THE JOURNAL OF
Engineering Education

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December, 1955 Vol. 46, No. 4

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The American Society for Engineering Education

Route Surveys and Construction

(Third Edition of *Route Surveys*)

By **HARRY RUBEY**, *Chairman of the Department of Civil Engineering, University of Missouri*

The third edition of this well-known textbook, based on sound practical and academic experience, maintains its fundamental approach. It emphasizes professional civil engineering, including construction, contracting, management, and practical photogrammetry. Unusually complete tables and problems support text material. *To be published Spring, 1956*

Electronics and Electron Devices

(Third Edition of *Fundamental Electronics and Vacuum Tubes*)

By **ARTHUR L. ALBERT**, *Professor of Communication Engineering, Oregon State College*

This edition presents the fundamental concepts underlying electronic developments. The author has revised and modernized the previous edition to contain chapters on solid state devices (including an extensive treatment of transistors), a chapter on magnetic amplifiers for use in electronic and control circuits, and a chapter on wave shaping. *To be published early 1956*

Principles of Turbomachinery

By **DENNIS G. SHEPHERD**, *Professor of Heat Power, Cornell University*

Here is a text which provides an integrated treatment of the principal types of turbomachinery (pumps; fans; compressors; steam, gas, and hydraulic turbines.) The book treats the principles of all forms of turbomachinery, proceeding from the general to the particular, in sufficient detail to provide a good command of major design and performance factors.

To be published early 1956

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ANNUAL MEETING—IOWA STATE COLLEGE
Ames, Iowa June 25–29, 1956

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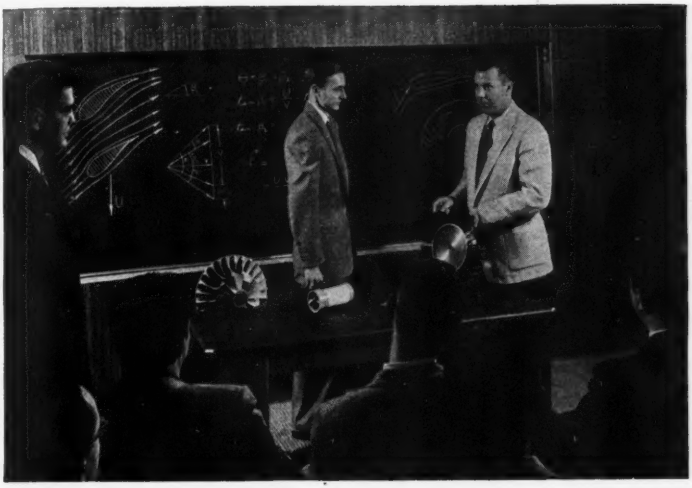

Education
after graduation

THIS picture was taken at the vast new General Motors Technical Center.

It shows recent engineering graduates attending a blackboard session, as part of a typical General Motors training program.

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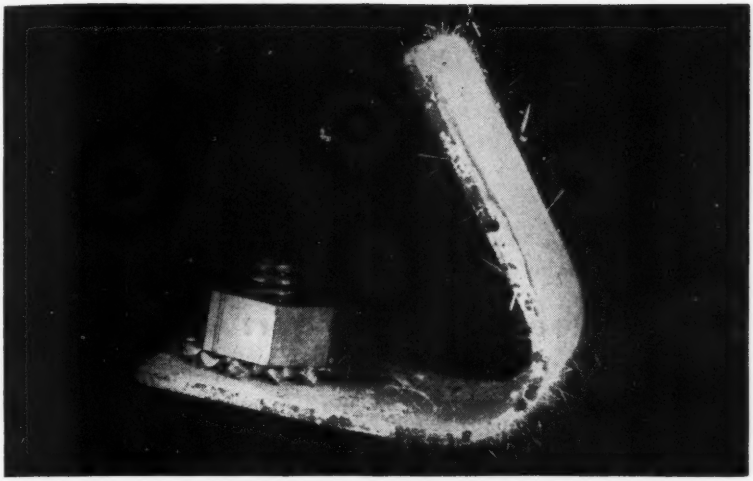


Whiskers on tin-plated steel, enlarged 6 times. Immense yield strength of metals in whisker form was discovered by Bell scientists.

The clue of the metal whiskers

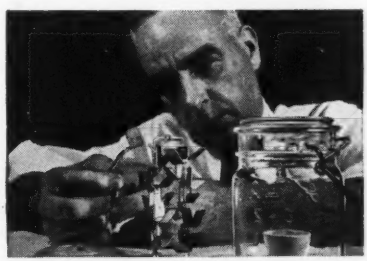
Close observation at Bell Laboratories often turns "tremendous trifles" into important scientific progress. Such a case occurred when short circuits in wave filters seemed to be associated with a zinc-plated mounting bracket.

Scrutiny disclosed a whiskery growth on the zinc plating. Similar whiskers of tin were found on tin-plated equipment. Studies showed the whiskers to be tiny single crystals of metal.

Suspecting that these unusual crystals might be of essentially perfect structure, alert Laboratories scientists saw an opportunity at last to test an important metallurgical theory.

The scientists studied the whiskers, grew larger ones, and showed that the crystals had enormously high yield strength as predicted by the theory for perfect crystals—a strength far greater than for the same metal in any other known form. This clue has opened new frontiers in the study of what makes metals strong or weak, and has excited metallurgists all over the world.

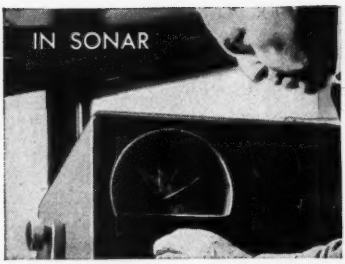
Thus, another advance comes from the Bell Telephone Laboratories habit of scrutinizing *everything* that can mean better telephone service.

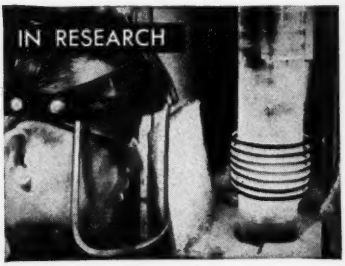


Through the study of thousands of specially cultivated whiskers, Bell scientists seek to prevent treacherous growths in telephone equipment.

BELL TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields





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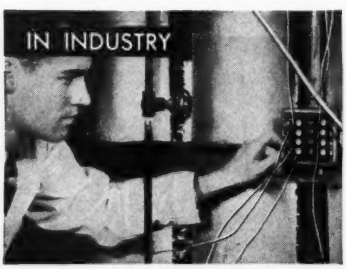

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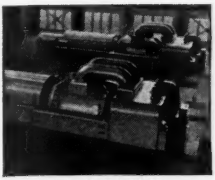

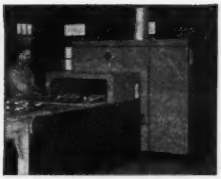

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McGraw-Hill Books

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By JOSEPH STILES BEGGS, Hughes Aircraft Company, Culver City, California. *McGraw-Hill Series in Mechanical Engineering.* 418 pages, $6.50

An advanced text on mechanism and reference book for the practicing engineer for the analysis of mechanism and a source of mechanical movements. The choice of notation and the use of the canonical vector equations of relative velocity and acceleration offer the student an almost standard approach to the analysis of mechanism, and result in the rapid facility and understanding in solving complex problems in mechanism. In order to illustrate the relative merits of the graphical and analytical approach, several mechanisms are analyzed by both methods. A glossary of terms is included in an appendix, and a bibliography, divided into eleven categories, may be used as reference independent of the text.

MACHINE DESIGN

By JOSEPH E. SHIGLEY, Clemson Agricultural College. In press

One of the most modern, forward-looking textbooks for Machine Design courses taken by mechanical engineers. It is intended as an aid in the teaching of creative machine design by placing a strong emphasis on synthesis. The development of the relations between the design specifications and the method of analysis or synthesis used in the solution presents an unusually scientific treatment and broadens the scope of machine design. Part I of the book constitutes a study of the design of fundamental machine members. Part II applies the principles developed in Part I to the study of various design approaches to a group of common machine elements.

BOUNDARY LAYER THEORY

By Dr. HERMAN SCHLICHTING, Braunschweig, Germany; translated by J. KESTIN, Brown University. *McGraw-Hill Series in Mechanical Engineering.* 556 pages, $15.00

A Pergamon Press import translation of the classical German work including material previously classified confidential or secret. The book introduces the mathematical and physical background of the problems involved in the motion of viscous fluids. The basic equations of the boundary layer theory as they are derived from the Navier-Stokes equations of motion are discussed in detail. The boundary layer theory is then extended to the laminar and to the turbulent boundary layer, and attention is given to the problem of the development of turbulence. Emphasis is on the fundamental physical ideas rather than on mathematical refinement.

DYNAMICS OF MACHINERY

By J. B. HARTMAN, Lehigh University. *McGraw-Hill Series in Mechanical Engineering.* In press

A new and authoritative text covering the techniques used in the design and control of modern high speed machinery and the analysis of its performance. It reexamines dynamics from a more mature viewpoint; extends two-dimensional consideration of kinematics and dynamics to the three-dimensional case, by means of vector notation; and provides a transition from basic work in mechanics to more advanced graduate work in dynamics. It shows the student current practical applications of mathematics and dynamics and introduces the mechanical engineer to certain mathematical techniques now becoming widely used in the literature of automatic controls and servomechanism.

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Do You Know—

▶ Now it is December and the Christmas season already is here! To all of you I want to wish a sincere and very Merry Christmas. The office staff joins me in extending these greetings. We sincerely hope that "Peace on Earth, Good Will toward Men" will be a reality for all of you, and that each of you can look forward to the New Year with enthusiasm and hope, the hope that must spring eternal if we are to do better jobs of teaching.

▶ While each of you is making your New Year's Resolutions to do a better job than ever before, there also will be a few new things in ASEE during the coming year. This is the last issue of the Journal for which Professor C. E. Watson is responsible; Professor E. C. McClintock, the new Editor, "takes over" in January. In singing Auld Lang Syne on December 31 we should turn to Professor C. E. Watson who has capably served the Society for many years as Editor of the JOURNAL and Assistant Secretary. "Wat" stepped in when help was sorely needed, and his big shoulder on the wheel brought results which the Society appreciates. And in saying thanks to you for the services you rendered, Wat, we also wish you well in whatever your new extra-curricular activities will be. Your many friends will continue to look for you at the Annual Meetings.

▶ In order that the Society and its membership have a better opportunity to know of the work done by its representatives to other organizations and committees, all members so appointed this year have been asked to submit a report of their activities at the end of the year. Such information as will be of general interest to the Society will be printed in the JOURNAL.

▶ When mailing lists for summer schools, etc., are made up by Divisions there is a need for knowing the Divisional interest of each *Administrator*. It is too late to do much about the '56 Yearbook, but we want to get started for the following year. So, if you are listed as an *Administrator* in the Occupational Distribution of Membership, either educational or industrial, please inform me of your divisional interest. Some of you asked that administrators be listed twice, but the Executive Board believed that listing the divisional interest after the title of the administrator was a satisfactory procedure to follow.

▶ Most Section Chairmen have been sending copies of their programs and minutes of meetings to the Secretary, and he is pleased to receive them. It is now requested that a copy *also* be sent to the Vice President in charge of general and regional activities, F. C. Lindvall, Chairman, Division of Engineering, California Institute of Technology, Pasadena, California. This procedure will enable him to become better informed on one aspect of his duties.

▶ At the Annual Meeting several suggestions were received that the Society should adopt some kind of a membership card as a receipt for dues payment. At its September meeting the Executive Board questioned the merit of the additional office work and expense and agreed not to depart from the present method of having the members' check serve as his receipt.

▶ Several inquiries have been received from time to time about the establishment of a clearing house or employment service for retired (and other) personnel, at the Annual meeting as well as throughout the year. The Executive Board at its meeting on 10 September agreed it was not a function of the Society to operate an employment service, particularly since Engineering Societies Personnel Service,

Inc., already has been established to serve the engineering profession. Most of our members probably are also members of one of the societies sponsoring that service.

► The Drawing Division is having its annual Midwinter meeting on January 27 and 28, 1956, at the Illinois Institute of Technology. Between 100 and 150 usually attend this meeting but indications are that this year's attendance will break all previous records. Highlights of the program are the two General Sessions at which technical papers will be presented and an inspection trip through the Chicago Tribune plant.

► The College-Industry Conference, sponsored annually by our Relations with Industry Division, has a "Humanistic-Social" theme this year. The dates are January 25 and 26 and the place is Marquette University, Milwaukee, Wisconsin.

► The Executive Board has formally approved the plan to submit all Section-winning papers of the YET Paper Contest to the Editor for possible publication in the JOURNAL OF ENGINEERING EDUCATION, and recommends to the Editor that he encourage the YETs by publishing as many as possible of the Section-winning papers. The Executive Board also recognizes that any paper submitted in a Section contest—even if it is not the winner—can be submitted to the JOURNAL for publication, just as any other author can submit a paper for publication.

► Don't forget that ECRC's award for outstanding contributions to research in engineering and engineering sciences in American colleges and universities will be awarded for the first time at the 1956 Annual Meeting. The recipient of the award is to be selected annually on his achievements in and contributions to one or more of the following areas: original research, research administration, leadership influencing the productive research of others, and the effective application of research results to the advancement of engineering education. Nomination forms and a brochure explaining the award have been sent to all Deans, Directors of Research, Members of the General Council, and Section Chairmen. Additional copies may be obtained from the Secretary's office.

► Please note that the audit for the fiscal year 1954–55 appears on page 397. From its examination it becomes apparent that the change in dues structure of a few years ago is enabling the Society to reach a sound financial position. Despite the increase in expenses resulting from the change in Secretary and the moving of the Society officers from Northwestern University to the University of Illinois, the Society operated "in the black" and was able to add a significant amount to the unappropriated reserve. The Finance Committee has recommended that this reserve be at least 70% of the operating expenses for one fiscal year. We haven't reached that goal yet, but it is coming closer. But in feeling good about the budget don't overlook the large incomes from JOURNAL advertising and dues from institutional members. Maintaining these totals at a high level means the making of constant efforts—by your officers, appropriate committees, and by *you*. Each of you, as an individual member of the Society should do all you can to interest industries in membership and in advertising. Just recently I made a casual remark to a salesman about the JOURNAL being a good place for his firm to advertise. Two months later we ran their first ad! Most of you have salesmen calling on you, how about you giving JOURNAL advertising a plug and selling him?

Merry Christmas to all of you from all of us!

NAOMI GARMAN
LOUISE CHAMBLISS,
ELSIE O'BRIEN
E. C. MCCLINTOCK
W. LEIGHTON COLLINS,
Secretary

Industrial Research and a Profile of the Research Worker*

By DR. E. W. ENGSTROM

Executive Vice President Research and Engineering, Radio Corporation of America

An industrial research administrator should be very much at home among engineering college administrators and directors of engineering college research. These three fields of endeavor have much in common. The engineering college provides much of the trained personnel which is so essential to industrial research. Sometimes industrial research provides experienced leadership for the engineering colleges. The engineering colleges are also the producers of research results important to industry. Some of these results are obtained in cooperation with industrial research laboratories. Others are independent contributions of engineering colleges. Never have relations between engineering colleges and industrial laboratories been closer or more friendly.

I shall present for your consideration ideas, principles, and facts which have been developed for their application to industrial research. That they have some application to the engineering-college field I have no doubt. However, I leave it to you to find such utility as they may have in your particular lines of endeavor.

First, I shall trace some of the steps whereby the scientist and the engineer came to their present status in industry. This will serve to emphasize the team concept in industrial research and technology. This concept is basic to the solution of a large proportion of the problems of industrial research administration.

A second concept of equally wide application is that of the importance of the human nature of the research workers. In the second portion of my paper I shall, therefore, discuss what industry requires of the research worker and the character and motivation of the individual research worker as we find him, not as we might wish him to be. Much of what I shall say on this subject is based upon an informal survey which was conducted among my associates at RCA Laboratories. The purpose of the survey was to obtain a more objective view of the research worker and to broaden our comprehension of the human side of research. To the conclusions of this survey I have added from my own experience.

Environment in Research

Until about one hundred years ago neither science nor engineering was recognized as a normal component of industry. During the Industrial Revolution of the preceding century, industrial development stressed empiricism rather than science. Progress depended to a large extent on the development of machines. This development, in turn, depended on mechanical inventiveness.

A century ago, research men in the universities were beginning to lay the foundation stones of modern science. This university research was conducted without any conscious consideration of practical applications. It had no connection with industry. This fact I emphasize because of its importance to an understanding of the scientific work of the time.

The art of engineering goes back to antiquity. However, the professionally trained engineer did not appear on the

*Presented at the Annual Meeting of ASEE, ECAC–ECRC Dinner, Penn State University, June 21, 1955.

American industrial scene until after 1850. From 1850 until 1900 both the inventor and the trained engineer played important roles in the translation of scientific results into practical applications. In these advances the trained engineer gradually assumed a larger part. In many instances he became an inventor as well as an engineer. The rise of the engineering college was both a cause and a result of this rise of the profession of engineering.

At the turn of the century, understanding in the physical sciences made a great surge forward. This, like the previous scientific advances, was the work of research men in the universities. There was the discovery of X-rays, electromagnetic radiation, the electron, radium. The nature of radioactivity was revealed and the development of the quantum theory was begun. We might well consider this period as the beginning of modern science.

Before this time, almost no scientists were employed in industry. In fact, many scientists of the late nineteenth century felt that a connection with the application of scientific discoveries placed a stigma upon them. Accompanying this attitude, experienced people in industry, including engineers, thought scientists to be hopelessly impractical.

Technology prior to 1900 was not complex and scientific knowledge was limited. Intense specialization was not required to achieve expertness. This, however, was soon to change. Specialization became a necessity, both in science and in engineering.

After 1900, scientists in slowly increasing numbers were employed in industry. The beginning of this association of scientists with industry marked the birth of industrial research. Science, thereafter, came to have increased meaning and purpose in industry. Working relationships between scientists and engineers were developed. Research by teams of scientists and engineers began.

At the beginning of this liaison between science and industry, the place of the engineer in industry was already well established. The engineer's functions were clearly defined and understood.

As the scientist-engineer team developed, the old-fashioned inventor began to disappear. I mean the inventor with natural aptitude and intuition but little knowledge of science. This was a natural consequence of the increasing complexity of technology. However, the natural aptitudes of inventiveness had not disappeared. They had simply ceased to be individually conspicuous in the old way. The individual contribution in modern technology reflects a background comprising a great variety of specialized scientific and technical skills. Invention now flourishes in a setting and atmosphere of science, an environment planned for creativity and invention.

Now at mid-twentieth century, the places of the scientist and the engineer are both well established in industry. A full partnership has developed. This is so much the case that the earlier clear-cut distinctions of function now cannot always be recognized. A bridge of communication has been formed. This bridge is between the scientists and engineers in industry on the one hand, and the scientists in the universities on the other hand. The old divisive feelings are gone. The practical applications of science have been greatly speeded as a result.

However else we might characterize the fast-moving last half century, it was above all an age of science. This was primarily the result of two developments—the organization of the scientist-engineer research team, and its acceptance in modern industry. The growth of research in the engineering colleges, which led to the organization of the E. C. R. C., played an important part in this development.

Before the twentieth century, as I have said, scientific advances were made by research men in universities, working without thought of applications. New products were primarily due to the independent inventor, working with little scientific knowledge but with great natural aptitude.

The growth of the research team, composed of theorists, applied scientists, and

development engineers, is distinctly a phenomenon of the twentieth century. In the period prior to the turn of this century, scientific progress did find practical application. However, it was at such a slow rate that a scientist who conceived a new theory rarely lived to see the utility of his idea. Now, with our modern research teams, research men can formulate a new concept. They can see it applied in some positive way to contemporary living. They can still be on hand to contemplate the impact which it makes on the world, whether for good or for ill.

The Research Worker

Today, forward-looking industries are fully aware of the possibilities of research. They are investing more and more in research. Research has taken an important place in business administrative planning. All this is done because of the conviction that research is necessary and provides long-term benefits.

We do not now question the place of research in industry. Rather, we ask how may industrial research be made more effective.

An effective research team must include creative people having all the needed skills. Also, it must be so organized and supported as a satisfy the motivation of these creative research people.

First, the research team must be so constituted that its members work smoothly together.

Secondly, the team must be organized so that there are proper cooperation and understanding between the research workers and the nontechnical service personnel.

Thirdly, there must be cooperation between the members of the team and the development and production engineers who must carry the research results into commercial production.

The industrial research organization should take into account the personal characteristics and motivation of the research man. Such an organization is in the best position to integrate its creative people into productive research teams meeting these requirements. Likewise, the research man should understand his own personal characteristics and motivation and the personal characteristics and motivation of his colleagues. With this understanding he is in the best position to select employment which will give him continuing satisfaction. Therefore, it is valuable to consider these matters.

We have talked and heard much recently about the great shortage of engineering and scientific personnel, yet America does have a large reservoir of talent. It is not unlimited but neither has it ever been completely tapped. The problem of manning our growing research laboratories is one of recruitment, of stimulation and encouragement. Suitably talented young people must be induced to complete the proper university training. The engineering college and the A.S.E.E. are making an important contribution at this stage.

Do we know what to look for as we recruit men for research? How can we make the best use of the people now engaged in research? We will have insight for the solution of this problem if we gain a better understanding of the kind of men needed for industrial research and of the character and motivation of the individual men now engaged in research.

It is evidently not possible to draw a single profile as an absolute standard for the man in industrial research. There is no ideal profile of the research worker as industry would like him to be. Nor can the actual worker, as we known him in the industrial research laboratory, be represented by a single profile. Since research workers vary as they do, it is fortunate that the requirements of industry vary also. These requirements vary for different units of industry. They vary for differing outlooks on research, and with the differing ideas of the particular persons administering the research. As we look at research workers as people, as we examine their personal likes and dislikes, as we take into account their individual and collective characteristics, many variations are found. There are as

many combinations as there are individual research workers. Nevertheless, a pattern of the nature of the research worker seems to develop. It is this pattern which we shall examine now.

Industry's Requirements for the Research Worker

What does industry look for as it recruits men to carry on its research programs? What are the requirements for a successful industrial research worker?

1. *Creativeness*

Among all who participated in our survey, there was general agreement on one requirement. Creativeness was placed at the top of the list of required characteristics. The creation of new understandings, new principles, new products, or new services—these identify an activity as research. Therefore, creativeness must be a basic research requirement. Members of research staffs are not equally creative. In fact, a staff composed exclusively of highly creative members would be unmanageable. On the other hand, a staff of noncreative members would be sterile. A research staff is effective when all its members respond to originality, when all have some degree of originality themselves, and when some of them are highly creative.

Creativity does not respond to attempts at definition or specification. There are no measures of creativeness which may be applied to an individual during pre-employment interviews. The creativeness of a research worker is not learned by brief contact with him. It is learned by observing him in extended living, preferably in a research environment.

Those who conduct employment interviews have various opinions and convictions regarding the gauging of creativeness. However, our experienced interviewers do not feel that they can estimate creative ability with any practical degree of accuracy in an interview. In general, the interviewers recommend employment if a young man shows a good reasoning ability and a good grasp of fundamentals. This is true almost regardless of other desirable qualities which they think he may lack.

The interviewers are concerned about creative ability or promise of creativeness. In spite of this concern, they make few positive statements in their interview reports regarding this important characteristic. They believe that persons who cannot reason clearly from fundamentals are not likely to be creative in research. From this belief stems the emphasis placed on the ability to reason clearly from fundamentals. Similarly, our interviewers have regard for broad knowledge and extensive interests. This is because of the close relationship between creativeness and the characteristics of imagination, and the urge to investigate and to learn.

All this is important because a research organization thrives if it recruits creative members for its staff. It is also important because a research man prospers if he possesses creativeness. The research administrator needs to know a prospective staff member's promise of creativeness and the prospective research man needs to know his own potential creativeness.

> *Industry expects its research workers to possess originality and to develop and use their creative powers.*

2. *Training*

Training in fundamental science is second only to creativeness as a requirement for the research worker. Scientific training is placed second to creativeness. This is because all other assets, including good scientific training, become ineffective without the creative mental traits which I have been discussing. However, creative ability must be backed by fundamental knowledge and specific skills if the research worker's creation is to mature into useful form.

Knowledge and training in specific fields are valued but they are definitely secondary in importance to an understanding of the fundamentals of mathematics, physics, chemistry, or engineering.

Industry does not expect all its workers to undergo a standardized training any more than it expects them all to possess equal creative talents. It is usual for aspirants for research positions to acquire or to desire university training at graduate level. Such preparation is valuable because of the knowledge and training it provides. It is valuable also because it adds another stage to the selective process by which it is established that the particular person is both interested in and suited for research.

For the research worker, the educational process, the acquiring of knowledge, or the development of skills should never diminish or cease. The research process itself is subject to the same obsolescence that it brings to the objects of its research. The research worker, therefore, must continue to be a scholar of science.

Knowledge gained in the university may be looked upon as a set of research tools. All agree that certain of these tools are basic and necessary. It is essential to have the ability to put the tools to use and to acquire supplementary tools as the need appears.

Industry expects its workers to have acquired basic scientific training, to know how to use it, and to continue to improve their knowledge and skills throughout their research careers.

3. *Character*

When these requirements for the research worker were first set down, following our survey, character was placed as the first item. It is still considered the basic requirement. However, it must, for practical reasons, follow creativeness and training in our list of requirements. Often character is not given appropriate consideration by younger research workers, nor do they appreciate the importance placed upon character by research administrators. Perhaps research administrators themselves have not adequately evaluated the importance of character. Whether or not it is so designated, character is a prime requirement. Integrity of purpose is essential to any research. Research deals with nature, and nature does not reveal her secrets unless the quest for them is conducted with technical and scientific accuracy and honesty. Complete reliability in prosecuting a research program is richly rewarded, yet it is rarer than one might think.

Industry expects its research workers to be dependable and of good character.

4. *Vision*

The research man must also have vision. He needs the ability to visualize the possible results of an investigation. He needs to see the application of a technique before its development is complete. Creativeness coupled with vision to treat the creation objectively makes for greatness in research.

5. *Energy—Drive*

Having found creative insight, one then looks for initiative. It is initiative that gets the research under way. Once the research is under way, one looks for enthusiasm to support the drive for progress. One looks for courage to take large steps into the territory of the unknown. One looks for perseverance to continue even though the going becomes difficult and discouraging. One also looks for persuasiveness in dealings with assistants, associates, and superiors. All these traits are manifestations of energy and intensity of drive. They represent, when accompanied by the necessary abilities, the potential for deep penetration into the new. They reduce the speculation involved in research by insistence upon positive and useful results.

Industry expects research workers to be energetic and to drive their research forward toward established goals.

6. *Scientific Inquisitiveness*

Research workers who are extremely productive of new ideas are persistently

expressing scientific curiosity or inquisitiveness. They have a continuing and unquenchable thirst to understand old and new situations and to relate these to other situations.

Industry expects its research workers to be inquisitive in all matters concerned with the fields assigned and the research objectives established.

7. *Practical Outlook*

Industrial research is done for the benefit of the industrial organization supporting it. In order to be of greatest benefit to its industrial sponsor, a research program must have a practical outlook. Not all research results are positive. Many results are of only nominal worth. However, a well planned and well executed program should provide results which are rich in current or potential values. Such research can be done best in an atmosphere of common sense. Research is sometimes thought of in lay circles as an ivory-tower enterprise. This is certainly an outmoded, if not a completely erroneous, impression. In research, as in other fields, enhanced results are obtained by the use of common sense in the establishment of objectives and in the work to attain them.

A practical outlook develops with training and experience in a suitable environment. Constructive action should be taken to begin the development of this practical outlook while the prospective research worker is still in the educational institution. The educational institution should be certain that its staff members are equipped by attitude and by experience to teach this practical outlook by example. The new research worker in industry should be given early indoctrination as to practical values. He should respond to practical considerations throughout the development of his career.

Industry expects its research workers to have and develop a practical outlook, to approach their work with common sense.

8. *Attitudes*

A research worker's attitudes are observed at the pre-employment interview. They continue to be observed as long as his employment lasts. For the prospective staff member, the initial approach is important. Does he show interest? Does he indicate willingness to work and prove his value? Does he give the impression of being suited for research? These attitudes become still more important in a practical sense as the research worker faces his first, second, and succeeding tasks. Then he begins to reflect his attitude in dealing with associates and superiors.

The complexity of modern research demands that the work be performed by a team. Effective team research necessitates a balance between one's personal ambition and one's understanding of the rights and ambitions of one's associates. Productive teamwork also requires an interest in the functioning of the laboratory as a whole, an interest which will generate ideas for other groups as well as one's own, an interest which will lead to an understanding of the place of particular projects in the program of the entire laboratory. A research organization can tolerate a few self-centered, temperamental, individual workers. However, if the organization is to thrive, nearly all its members must be cooperative. They must be able to get along with each other. They must be imbued with the spirit of team play.

Industry expects its research workers to have wholesome attitudes toward their work and toward the persons with whom they come in contact. Industry expects its research workers to understand and practice cooperation.

9. *Research Environment*

Research organizations that have established records for fruitful results have also developed understanding of the nature of research and the characteristics of the research worker. These organizations,

in administering their research programs, are tolerant of new staff members. They understand the speculative nature of research. They appreciate the need for the research worker to keep his knowledge and training up to date. They support him in his desire to do this by individual study and through outside contacts.

The research worker is, as a result, in an atmosphere of freedom in the use of his time. His direction may be more by suggestion than by specification. This is proper, for experience indicates that research thrives in such an environment. However, the research worker must understand and respect the purpose of these freedoms and tolerances if they are not to be abused.

Industry expects its research workers to make proper use of the freedoms of the research environment.

10. *Mental Youth*

While the evidence is by no means conclusive, there is reason to believe that the most revolutionary creative thoughts come to a few research workers during their first decade of work. It seems that the average research worker's most original and creative work comes before the close of his second decade. His best balanced contribution of original work, tempered by experience, is likely to occur during his second or third decade. Beyond the third decade, the average research worker's strongest characteristic is likely to be his judgment, his qualities of leadership, or his effectiveness in training younger staff members. For some, however, these generalizations do not apply. A few complete their careers with creativeness undiminished.

The relationship of age to creativeness is a relatively unknown field. We have too few facts, and current knowledge is not controlling as far as the individual is concerned. What industry requires is a continual intake of young research workers and an understanding of how best to use those of advancing age.

Industry expects to freshen its research staff by continually adding young members, and industry hopes that a share of its research workers will retain their mental youth.

11. *Other Desirable Qualities*

There are several additional qualities which are desirable in a research worker. I shall briefly mention salesmanship, manual dexterity, and the ability to speak and write clearly.

a. *Salesmanship*

Industry expects its research workers to be salesmen of research. The research worker must first sell his ideas for a research project to the Research Director before work can begin. After finishing a research job, he must sell the results to those in charge of commercial activities.

b. *Manual Dexterity*

A degree of manual dexterity is of considerable value in today's research. A large part of modern research employs experimental rather than theoretical techniques. Therefore, it is important for the research worker to be able to transfer his ideas quickly into successful practical experimentation. Ability with one's hands is helpful in this.

c. *Ability to Speak and Write Clear English*

The ability to express oneself well in speech and writing is important to the research worker. This is because the results of research are mainly ideas and these must be conveyed to others in words and diagrams. The research worker who lacks a good command of language is severely handicapped. He is unable to communicate satisfactorily the results of his research to those who could make good use of them.

Summary

Having reviewed in some detail industry's requirements for the research worker, I shall now summarize.

Insofar as they can choose, industrial

laboratories pick for their research teams men who are creative and men who are well trained in the fundamentals of science. They choose men of good character, men of vision, men of energy and drive. They look for men who have scientific curiosity but who, at the same time, have a practical outlook, men who practice cooperation and can make good use of the freedoms of the research environment. They hope for research workers with continuing mental youth. Industrial laboratories also value research workers who are good salesmen of research ideas. They value men who are adept with their hands, and who can express themselves well in speech or writing.

When we are considering a person with reference to a particular job, we do not always weigh the desired research qualities the same as when research qualifications are discussed in general terms. We do not want exactly the same type of person to fill all industrial research jobs. Because of the nature of a particular job, any one or two of the qualities just discussed may be required to a greater degree than the others. A proper balance of men with varied characteristics is the secret of an able research team.

The Research Man, a Human Being

Having examined what industry requires of the research worker, I shall now direct attention to the research man as an individual, as a human being.

1. *Motivation*

Any list of desirable qualifications for men in research runs the risk of being over-idealized and utopian. It is, without doubt, necessary to have an understanding of the essential qualities which make for a successful research worker. But, this is not enough. We also need to know concretely the actual men in research. We need to know the make-up of the research worker—how he is motivated, what factors draw him into research as a career, and what keeps him satisfied year after year.

In short, taking the research man as he is, and not as we would like to have him be, we need to know something about his thinking, about his desires, and about his needs as a human being. With these facts in mind, we can then discuss how he will fit into the modern research team and what we can expect of him as a member of that team.

Although our survey disclosed a wide difference of opinion regarding the characteristics of a research man, our associates seemed to agree fairly well on his motives.

a. *Intellectual Curiosity*

Everyone placed curiosity at the top of the list of motives. The urge to investigate and explore is the mainspring of the research man. His present curiosity stimulates more curiosity for tomorrow, and so on into the future.

When does this intellectual curiosity, this urge to investigate, first begin to show itself? There seems to be good evidence that it begins in childhood or early adolescence. Little by little, the scientist-to-be accumulates a large store of knowledge. He does this through his interest in natural phenomena and through his own observations. By the time he reaches high-school or college age, many of the "building blocks" that go to make up the research man are formed. Because of the great store of knowledge which he has accumulated subconsciously, he is able, even at that age, to reject almost automatically many unfavorable alternatives in seeking the solution to his scientific problems. In school he finds that he excels as soon as he begins to take courses in science. He finds a joy in learning that he never experienced before. The cels as soon as he begins to take courses arouses compelling interest, and his curiosity grows under the stimulation of scientific education. Sooner or later, he develops a burning desire to explore beyond the obvious and the known.

Another motive which urges the research man on to investigate and explore

is discontent with the current order of things. A good research man is not easily satisfied. He responds to the challenge of a problem. His imagination permits him to see possibilities for improvement, and his nature drives him to seek solutions.

b. *Will to Create*

The will to create is another important motivation for the research man. Most scientists take pleasure in creating something new. There are many in research who would pursue their investigations for their own personal satisfaction in accomplishment. They would do this regardless of papers presented, credit given, patents granted, financial rewards, or other types of recognition. However, the research worker does crave recognition from those with whom he works and, eventually, from those in his scientific field throughout the world.

Some say that the satisfaction the research man gets in his creating is a satisfaction of his ego. There is evidence that the scientist has a strong ego. It may be the same kind of ego that is satisfied by a man taking up a hobby. He enjoys demonstrating his excellence in his hobby, even if only to himself. He takes pride in showing himself what he can do.

c. *Financial Incentive*

How strong is the motive of financial reward? Does the research worker's dedication to a life of research mean that he is not interested in money? Certainly not! But it does seem clear that the financial incentive is not all important. Also of importance to the research worker are the facilities and opportunities to satisfy his curiosity and intellectual recognition for his contributions.

This does not mean, however, that the research worker disregards financial compensation. Neither does it mean that he disregards the dollar as a measure of success. But it does mean that the average research worker is not a fortune seeker, nor is he envious of those with large personal fortunes.

d. *The Role of the Wife in the Research Man's Motivation*

It should be noted that very often the research man's wife is more concerned about recognition for her husband than he is himself. Part of her desire for this recognition may be due to true respect for her husband's ability and performance. Part of it may be due to ambitions of more than keeping up with the Joneses. One of my associates has said that it might be more effective to give the prizes, awards, the compensations and the titles, to the wife than to her scientist husband. No matter what the source of the wife's ambitions, they are a real factor in the happiness and performance of the research man. Hence, they are another important element in the research environment.

e. *Idealism*

If the research worker is not strongly motivated by financial considerations, is he on the other hand an idealist? Here the evidence is not too clear. It is true that some enter the field of research with a vision of opportunities for benefiting mankind. On the other hand, many others see in a research career an occupation not more worthwhile than many other professions. They see only one for which they are well fitted by their particular abilities.

Sooner or later, the idealist may come to see that a scientific discovery is not of itself either good or bad. It is neither moral nor immoral, it is amoral. The true scientist will reach out to discover the unknown regardless of the consequences to humanity and regardless of moral implications. But, this brings some scientists to a dilemma. For example, during the war, many research men were "brought up short" in contemplating the death-producing instrumentalities they were creating. More recently, there are those atomic scientists who are unable to reconcile themselves morally to the new order they helped to create.

2. *Personal Characteristics*

Most of those questioned in our survey believe that the variations in human characteristics or personality traits are as great among research men as among human beings in any other grouping. Nevertheless, they believe that the research man does tend to have a few particular personal characteristics.

For one thing, the research man is often found to be essentially an individualist. He usually has strong opinions. He may object to being told what to do or how to do it. On the other hand, he is apt to be tolerant, even if only to a limited extent. He has proved himself wrong just about as often as he has proved himself right. Consequently, he does not insist that his way of thinking is the only way.

The research man is likely to be retiring rather than outgoing in personality. He may not start out that way, but his single-minded interest in research may make him so.

The research worker is a straight thinker. He is logical minded. He is able to reason objectively, particularly in matters of scientific research. He proceeds from a premise to a conclusion. He will not be persuaded of the truth or falsity of a certain scientific theory until he reaches that conclusion by logical processes.

Conclusion

I have sketched the developing environment for industrial research. I have outlined what industry requires from the research worker. I have also said something of the character and motivation of the individual in research.

I have stated that it is not possible to draw one standard profile for the man in research, that this concept of a "standard member-of-staff" should in fact be avoided. It would be regrettable if we should set up standardized criteria and should begin to apply these criteria rigorously in employing members of a research staff. Research thrives on freshness of viewpoint and on differences of approach to the solution of problems. These conditions we achieve by varied environments of training, by differences in the prominence of the several characteristics we have been discussing, and by a continual flow of persons newly come from the halls of learning.

Our great problem today is the proper cultivation and exploitation of the nation's intellectual resources. We must learn to make the most effective use of our research staffs. We must know what we want and what we can expect to get from the research worker. We must understand his motivations and his personal characteristics. Having an understanding of these things, we must provide an environment conducive of good research. We must use creative imagination in the administration of research. We must follow this with sound engineering and good business planning. This is effective research, the kind of research which will maintain our position today and control our destiny tomorrow.

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Uses of the Laboratory in the Teaching of Electric Machinery Courses*

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The use of the Laboratory in courses on Electric Machinery is related intimately to the broader issue of what the true educational aims of these courses are. It is the uncertainty of these aims that is the matter of concern.

We may recognize that courses and laboratories, in established forms handed down through decades, have little appeal to most students and—even worse—seldom seem to contribute anything lasting to their professional stature. However, before leveling accusations of obsolescence against these courses, before raising the specious argument of the more glamorous competition of newer subjects, and before accepting drastic decisions in the reshaping of the curriculum, it may well be in order to examine how this lamentable situation has been reached.

Indeed electric machines are no longer in a stage of dramatic development. Their basic types resulted from some marginal thinking of Physicists who, some eighty years ago, were concerned essentially with the building of electromagnetic field theories. Technically minded people grasped the practical significance of those inventions in terms of industrial conversion of energy and, with shrewd ingenuity, proceeded to their reduction to practice in a remarkably short time. Nearly all machines of present usage were found displayed in workable commercial form at the St. Louis Exhibition of 1904.

This technological development was accompanied and followed by a fruitful period of fundamental studies, investigating analytically the electrodynamical problem and also associated aspects, thermal and mechanical. Within one decade, i.e. up to the first World War, magnificent scientific treatises were produced, such as the classic ones of Arnold, which discussed comprehensively electric machine theory, both fieldwise and circuitwise, and gave sound criteria of design and experimentation in the laboratory and on the test floor.

Further progress went on from that point, of course, but soon the problems to be solved became more specific and exacting, reaching quite frequently beyond the level of undergraduate understanding and interests. (In fact, it is not the lack of problems, but rather their present formidable complexity that makes it comparatively difficult to choose suitable subjects even for doctoral dissertations in the field.)

The recognition that the largest part of the content of present undergraduate courses can be traced directly to treatises which are more than 40 years old, however, should not constitute an accusation of obsolescence in itself; the basic understanding of any given field of scientific knowledge is not a matter of passing fashions. But the accusation may be more properly directed to the general educational aims that we may intend to achieve in the curriculum. The purpose of courses on electric machines, as conceived some 40 years ago, was to prepare supertechnicians well versed in the immediate solution of everyday questions of design, testing and trouble-shooting of

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these machines. With the tremendous expansion of the art we have learned that all this is neither feasible nor truly desirable. Yet the readjustment of machinery courses and laboratory work to the changed needs seems to have taken place only in the narrow form of a retreating fight. One hears arguments about number of courses and units, about length and number of laboratory assignments; half-hearted concessions are made to "drop" this or that machine which may be technologically "less important" than others, reducing laboratory assignment to a minimum number of standard tests.

In a way, this kind of approach reminds one of tourists visiting a large gallery of art, pressed for time but duty-bound to "see" as much as possible. They may decide reluctantly to skip the third floor or even to limit themselves only to those works of famous painters which they understand to be a "must." Then, with an eye on their watch, they rush hurriedly to check that the frames of those paintings really hang where the guidebook says they should. The result is confusion and tiredness rather than enjoyment and art appreciation.

The Real Question

In our appraisal of the overall curriculum, at the Carnegie Institute of Technology, we have tried to discard completely the educationally fallacious argument that electric machines may be "important" in terms of their technological usage or in terms of statistics on electrical engineers employment. The question is rather whether the analytical and experimental study of electric machines is a subject in which the understanding of physical laws can be extended and deepened and in which significant engineering problems can be attacked profitably by engineering methods at the level of maturity reached by the students.

The answer is emphatically in the affirmative. Our rotating machinery courses are given in the two terms of the Senior year. The students at that time have in succession recovered from the early shock of the transition from high-school to college, have learned to understand what is meant by "engineering problems," and have acquired valuable concepts and techniques in field theory and circuit analysis courses. Now they can be presented with problems and situations which are realistic and comprehensive, and which they can tackle, without many of the artificialities and over simplifications and instructor's hints which unavoidably accompanied the presentation of problems at earlier levels.

The electromagnetic fields are understood in structures which are tangible and allow for all sorts of measurements; their significance in the process of energy conversion is appreciated. The subject is rich in examples in which formidable situations with time-varying parameters and with non-linearities of all kinds can be reduced, by inventiveness and the use of critically examined simplifying assumptions, to more accessible situations for which significant answers and results can be obtained and discussed. This constitutes a training in mental processes, which the student must certainly employ in professional life, if he is ever concerned with electrodynamic problems, either of conventional mechines, electromagnetic actuators or loudspeakers or any one of the many ingenious regulators and transducer devices of modern systems.

At the same time the study of electric machines offers a good transition from the electromagnetic field problem to the lumped parameter circuit analysis problem. "Equivalent" circuits of suitable kinds can be "invented" by the students, with a clear understanding of their scope, validity and limitations. Thus the study of the dynamic system behavior of the machine in terms of its terminal characteristics can be approached with an understanding reaching beyond the techniques of transfer functions and transforms which can hardly be postulated and used meaningfully without adequate feel for the underlying electrodynamic processes.

In this light we at the Carnegie In-

stitute of Technology have discarded the idea that the subject may just be an optional one. And we have moved away from "content" questions of the kind, "Should we teach the synchronous converter and spend laboratory sessions on it since streetcar substations nowadays use mercury arc rectifiers?" That machine offers an elegant example of a double energy conversion by the use of a common air gap field; we may consider it as a rich source of intelligent questions. Or we may choose to use for the same conceptual purposes some different machine or system. Of course, by proper organization and choice of the problems, a certain breadth of content can be achieved and some conventional technological information can be gathered. Undeniably this is a welcome by-product but it is not the essential aim of the courses.

The Laboratory as an Integral Part of the Course

The laboratory remains an essential educational tool in this kind of approach. Of course, it is no longer regarded as the place in which the student practices hooking up circuits (under rather artificial layout conditions), reading meters and neatly plotting these readings.

In fact we have de-emphasized the "3-variable problem" that seems to constitute the backbone of many laboratory experiments (not in the machinery laboratories only). "Three variables, x, y and z are interrelated (armature voltage, speed and load torque, or terminal voltage, field current and load, or plate voltage, plate current and grid voltage, etc.). Keep x constant, vary y and read z; repeat the run after having given a different value to x and so on. Then repeat the whole procedure two more times by permutation of the variables and then plot and cross plot these families of curves."

A couple of experiments of this kind, performed at some time in the student's career, may be sufficient. They have some value because they give to the student the beginner's thrill of seeing that curves and characteristics he sees in textbooks and catalogs are something real and obtainable by direct experimentation whenever the need for this arises. But enforced repetitions of this trivial kind of assignments without broader purposes is bound to engender lack of interest and curiosity and on the whole constitutes a most inefficient use of the limited time available in the curriculum.

Actually the laboratory is an integral part of the machinery course as it accomplishes two main purposes:

1) It offers abundant opportunities for demonstrations of the electromagnetic fields of the machine under direct, active participation of the students. This we find necessary because many concepts are elusive to the beginner and not adequately meaningful to him from his previous courses. Simple expedients, for instance the use of a few search coils, can clarify essential issues much better than any blackboard description and explanation.

2) It provides a method to be used concurrently with the analytical approach in the solution of problems. This we consider to be the most important point.

Some Examples

Examples of what is meant by all this can be given only in a sketchy and incomplete form here. Every interested teacher is entitled to have a certain number of preferred experiments of his own; the subtle question under discussion is not "which experiment should be performed?" but rather "which is its very purpose?"

For instance, at an early stage in the course the air gap flux density distribution of a d.c. machine is measured by the old gliding-pencil method. That is, voltages between one brush and a movable contact on the commutator are recorded. This can be done at no-load or, with some care, under load conditions. The interprettion of these readings for the assignment at hand involves some less than obvious concepts of time and space integrations. The results can be compared

with predictions from graphical field mapping. Actually the matter of flux density distribution could be avoided at that time in the course and by-passed with the simpler concept of flux per pole. But the latter concept, while adequate to develop standard formulas for the no-load generated voltage of a d.c. machine would be too narrow and indeed crippling for any further purpose. (It may be interesting to point out that this old experiment seems to have been among the first ones to be sacrificed in compromises aiming to salvage standard tests of standard steady-state performance.)

In the same light the air gap field of a.c. machines is investigated and understood with experiments on the single-phase and 3-phase induction regulators. Again this is done at an early stage as an indispensable introduction to the study of any particular alternating current machine. These investigations are accompanied by problems, analytical and experimental, dealing for instance with the static torque of the same machine with stator and rotor windings variously supplied with direct current. Numerical predictions result from the "Bil" reasoning or from virtual displacement approaches. In fact, concepts of torques and also application of Newton's laws to rotational motion seem to receive a most needed clarification in the Laboratory.

At a later time, the voltages induced in a full-pitch exploring coil on the stator of a 3-phase salient pole machine during a "slip test" are displayed on an oscilloscope and recorded photographically. It is recognized that the fundamental component of that voltage remains nearly unchanged, while the wave forms vary conspicuously throughout the test. This leads to a clear understanding of complex phenomena and factors of design and also to a lasting appreciation of the ingenuity and elegance of two-reaction theories. On the other hand standard tests of overall behavior ("The V-curves have the shape of a V") are found less useful in the same area as they add very little to whatever the student may have grasped before the performance of the assignment.

Incidentally, I remember how in my own experience as a student I managed to understand that a terminal voltage of sort appears at the terminals of a synchronous generator at no-load, and I understood also that the flow of load currents in the armature winding modifies this voltage with some secondary effects because of resistances and a few other semi-obscure phenomena. We did and overdid standard experiments on regulation, drawing vector-diagrams and using all tricks of the trade such as Potier triangles, derived for cases of round rotors and not too meaningfully applied to saturated salient poles, and what not. But the tremendous significance of the armature reaction fields in the process of conversion of energy dawned upon me only years later, when I had been for some time a junior design engineer in industry. (Of course, I may have been a particularly naive fellow).

Two more examples may help to illustrate the point of view.

As soon as the magnetization curve of a d.c. generator is determined by separate excitation, the significance of this information is put to use in a variety of problems, from immediate predictions and checks of self-excitation behavior to studies of the d.c. machine as a power amplifier with various types of feedback. Concepts of time of response, and gain and "figures of merit" are developed (without concealing their limitations) and compared with quite similar concepts arising in other kinds of power amplifiers.

Finally a laboratory problem is described that is usually presented in junior courses dealing with transformers. We have some moving-coil transformers for street lighting series distribution systems. One could study these devices with the "3-variable" approach (the counterweight, the number of light bulbs in series, the current). The students could be led to recognize that this constant output current device keeps the output current more or less constant. But this would be

an uninspiring waste of time. On the other hand the availability of these unusual structures in the laboratory may lead to a number of broader problems, involving study of leakage fields, the prediction and check of forces between coils, and a study of dynamic response to step changes of load and of the subtle question of steady-state stability that arise whenever the load has a capacitive component. Of course, light bulbs are not capacitive, and we are aware that these awkward regulators are being replaced in practice by devices without moving parts. But these factors are irrelevant in any decision to devote time to the study described, in the classroom, in the computation room and in the laboratory.

Coordination

It is obvious that laboratory work thus designed must be carefully coordinated with the other parts of the course. Analytical problems should be chosen in the classroom that lead to the immediate need or convenience of experimentation, conceivably followed by further analysis and also further related experiments. This continuously taxes the ingenuity of the instructor, but, by judicious choices depending on the equipment available, remarkable achievements can be obtained even with limited means. (On the other hand it may be noted that "platoon" systems in which individual groups are required to perform certain "must" experiments in cyclic permutation, out of step with the progress of the course, are of little use. Whenever it is found indispensable to expose students at a certain time to a certain experimentation for which no sufficiently large facilities are available it may be educationally preferable to combine groups or even to convert the assignment to a kind of demonstration performed with the instructor's participation.)

This interlocking of analysis and experimentation is the essence of engineering and deserves to be stressed even at the somewhat embryonic level of undergraduate college education. As laboratory and classroom problems become inter-related it becomes also easier to prevent the well-known evil of laboratory work: The lack of pertinent preparation and the failure of the students to really understand the purpose of the experimentation.

A question can be raised at this point: If machinery courses are intended to be primarily courses on electrodynamics and not on standard technologies is it necessary to have standard machinery laboratories in their customary layout? Can't we achieve the same aims using sub-fractional horsepower machines, on a bench or inexpensive educational "erector" models available on the market or different electromagnetic devices altogether?

Probably we could, to some extent. But small machines and erector models are not too well suited to significant studies at any better than qualitative level. This is so because those simplifying assumptions, that in larger machines allow the beginner to focus attention upon a comparatively limited group of phenomena at the time, often cease being reasonable. The high per-unit resistances and the poor winding distribution are some examples of these unwelcome and confusing difficulties. It is much more difficult to conduct a quantitative, nonsuperficial study of a kitchen clock motor than to evidence and evaluate reluctance torque phenomena in a conventional synchronous machine. Similar reasons may limit, though not necessarily exclude, the use of other electromagnetic devices for the educational purposes outlined at the undergraduate legel. A real advantage of the use of conventional machines in electrodynamic studies is found in the well established possibility to pitch the study at any wanted level progressing as needed, from the most elementary to the most sophisticated approach in a gradual manner.

Conclusions

It appears from all this that the use of the machinery laboratory within the educational aims outlined does not imply the

need for new and extravagant stunts. What is really needed is a continuous, thorough, critical examination of the meaning and worth of the experiments chosen, not in terms of some narrow technological information of non-lasting value, but rather in terms of their contribution to a deepening of basic understanding of the physical laws.

Indeed "basic" and "fundamental" by now are standard words of the educational vocabulary and the considerations just presented may well sound as an unnecessary repetition of truisms. Yet from time to time one wonders how often these words are only accepted and misused to rationalize on anachronistically unchanged attitudes. A nationwide examination, aiming at a search for promising young scientists to be supported with graduate scholarships, was said to have contained, among others, this question: "Of the following 5 methods proposed to calculate alternator regulation (list of names or abbreviations given) which one yields the lowest answer?" Anyone familiar both with the acknowledgedly semi-empirical nature of Test-Code prescriptions and with the huge theoretical difficulties of any reasonably adequate treatment of this problem may wonder whether it is seriously meant in some quarters that our training of young scholars should be directed towards the delivery of memorized pat answers, without even the benefit of references.

This seems to be so completely opposite to the aims we thing should be set in our courses and laboratories that renewed clarification and discussion may not be superfluous, after all.

In the News

The **National Science Foundation** has announced for 1956 approximately forty senior post-doctoral fellowships to individuals planning additional study and research in the life, physical sciences, and closely allied fields. Fellows will be selected on the basis of ability as shown by letters of recommendation, academic records, and other evidence of attainment. The final selection of Fellows will be made by the National Science Foundation. Successful competitors will be announced in March, 1956.

The **Atomic Energy Commission** has made available for the academic year 1956–57 a number of special fellowships in two relatively new fields of scientific endeavor closely related to the atomic energy program: industrial hygiene and radiological physics. The Oak Ridge Institute of Nuclear Studies will administer the fellowships for the Commission.

Thorndike Saville, President of the Engineers' Joint Council and Dean of Engineering at New York University, recently received the **American Society of Mechanical Engineers' 75th Anniversary Medal.** Dean Saville was chosen for the ASME's honor "in appreciation of his friendly cooperation and in recognition of his outstanding leadership in the Engineers' Joint Council and as its President."

Aim for Ames in 1956

Education by Research Training*

By JOHN T. RETTALIATA

President of Illinois Institute of Technology

This discussion of Education by Research Training will be confined, as closely as possible, to the value of research to the student and its consequent effect on the development of future leaders capable of creative thinking for the advancement of learning and human welfare.

Engineering educators have been long aware of the usefulness of research training to the student and have realized it is an essential step toward the development of the mature research worker whose labors explore the paths for mankind's progress. Because of the scope of the subject I have consulted with some of my colleagues engaged in research activities at our institution, and am privileged to have the benefit of their comments.

The subject is timely in this age of science and technology because these pursuits are sustaining our existence. And, research is the life-giving source of new technology. Many of us are concerned that our nation's scientific and technological research depends upon the efforts of less than one per cent of our country's population. Even this small corps generally knows only one facet and one specialism at a time. In the meantime, science is moving out beyond the world of daily, common sense experience into a universe that is stranger perhaps than we can imagine.

The situation places heavy responsibilities upon educational institutions. There is not only a tremendous and growing demand for more graduates to operate the technology but there is a serious need for better-prepared individuals who will advance the frontiers of science and technology. In today's world, persons who can think new and different thoughts, conceive new things and methods, and exercise honest inquiry and judgment are a priceless possession of humanity.

One of education's objectives is to instill in the student an attitude of enlightened appraisal toward society. This is an important objective because if it is neglected we perpetuate a static society. Obviously, society is not static . . . it wasn't, even in the Dark Ages. Civilizations always become more complex. This changes living conditions and moral standards. When there is unquestioned acceptance of everything as it occurs, decadence and destruction of culture are inevitable.

A research worker learns early that he can accept no premise as a valid one until it is proved. His research training is desirable because it educates him to maintain an attitude of intelligent criticism.

Intellectual growth results from the exacting nature of research endeavors. Research expands man's understanding and control of nature as he seeks to uncover new facts, new relations and new principles. To penetrate the unknown, the researcher must understand the known with great thoroughness and clarity.

Adds Interest and Significance

Research is the element which adds interest and significance to an educational program and, as such, is a proper and essential part of all education at the college and university level. It is important, alike, to both undergraduate and graduate

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students. Scientific research will have a lasting effect on the attitude of the student. After being appropriately associated with it he is no longer content with merely attending classes, but rather experiences a creative compulsion to contribute to the advancement of his field of study. This is a worthy characteristic of proper research training.

Further, research training permits the institutions of higher learning to provide students with fundamental principles and techniques which will be applicable to the solution of all problems. The volume of human knowledge has become so vast that the schools and colleges can present only its rudiments. Facts and information which are not quickly used are likely to be forgotten. Since it is not the intention of education to make factual depositories of our students, research training is an effective means to the acquisition and creation of knowledge, the formulation of hypotheses, the evaluation of those hypotheses by experiments and known facts, and the tentative and critical acceptance of solutions.

Another of the important benefits the student may derive from participation in research is the habit of critical evaluation . . . not only of the data which he may accumulate in his own experiments . . . but of conclusions derived from experimental observations and from published records of research performed by others. Evaluation of the published research of others in the same field as the student's own endeavors is most decisive. It teaches the student to become his own severest critic . . . of both his plan for experiment and of his interpretation of the data he may accumulate.

Research experience makes the student aware of the difficulties involved in all experimental procedures. As he learns of the possibilities of obtaining varied results by employing different procedures or a more enlightened approach, he realizes the dangers of pitfalls and the possibilities of manifold interpretations of data. Thus, research has a broadening influence in his education. The research-trained student will question all statements, will differentiate between opinion and fact, because the ever-widening technical approaches to the solution of his experimental problems have enhanced his educational experience.

Research instills in the mind of the student an attitude which provides him with a new perspective in other intellectual pursuits. It emphasizes the fact that the magnitude of our knowledge is dwarfed by truth yet to be discovered. He realizes that most textbooks are out of date by the time they are published, and that many of the research reports in the journals are similarly not current.

Additionally, the research student makes the valuable discovery that some of the principles found in the textbooks and journals are reliable and some are not. He develops a cautious approach. The usefulness of published information is seen in a fresh perspective. He learns to read widely and critically, fitting each new piece of information into the pattern of his previously-tested experience. Literature becomes, as it should, a tentative introduction and only a prologue to his further study and development.

If nothing else, research teaches the student that he must do thinking of his own. He is aware that the advancing front of knowledge possesses a fluidity which makes predictions of all possible generalizations, laws and principles uncertain. He learns that to keep up with the latest ideas and developments he must read widely, engage in conversation with others who are making similar studies, and maintain an inquiring mind.

His experience stimulates curiosity as well as the critical approach. As new ideas develop in his mind he becomes increasingly anxious for every opportunity to explore them and put them to the test of experiment. Thus, research pays off in the educational process. It neutralizes the deadness sometimes associated with textbook teaching and stimulates the student to do creative thinking. Research training presses the student to live and

grow and insures that his work will have new vitality.

Influence of Environment

Having enumerated the value of research training . . . to both the student and the educational process . . . it is appropriate to refer, briefly, to the fact that such training, alone, may not necessarily develop the vital outlook we desire. Researchers learn about pitfalls and the possibilities of obtaining different results by varying the circumstances. We, therefore, must consider the influence of environment on the student's ability to learn.

An environment of creativeness must be the goal of education, especially in the field of engineering. But creativeness must be cultivated by providing the student with the proper climate.

A student gets much of his inspiration for creativeness from his instructors. They, too, must live in a creative atmosphere which derives from constructive research activity. Instructors, engaged in research and consulting activities, can make their lectures alive with reports of their experience gained in the laboratory or industry. They can present advanced knowledge, not yet in the textbook, and by example inspire creativeness and a sense of professionalism.

As a partial digression, let me state that I have no intention or desire to engage in any discussion implying that teaching and research are incompatible, a situation that is sometimes asserted to exist. Certainly the instructor engaged in research has the advantage of bringing freshness to his subject, but since teaching is an art and not a science, it does not follow that he, therefore, possesses any special ability to communicate the import of research findings to his students. Conversely, because he is engaged in research does not mean that he has no interest in teaching and cannot be effective in it.

Similarly, we all know of many excellent teachers, not directly associated with research, who were particularly adept at elucidation. To be most effective, however, these instructors must keep their lectures current through a continual pursual of the literature in their fields. Obviously, this method does not possess the immediacy of direct research but can be satisfactory if conscientiously pursued.

When the instructor can be helpful and provide the right climate, the student can be inspired by research assignments. This is possible when the student senses that his advisor is deeply interested in research and in contributing to the advancement of knowledge in his field. The instructor's contribution may be only the reviewing and evaluating of articles for publication in the scientific and engineering journals . . . but it must be an indication that he is doing his part in the total effort of the world's scientists and research engineers. When there is evidence that the work of the laboratory is important and is respected by competent workers elsewhere, the student will develop a desire to contribute too.

This suggests a further feature about education that is provided through research training. Such training contributes to the development of sound character. It develops men of initiative and self-reliance, who are willing to accept responsibility and who will be creative and constructive future workers in their field of interest.

Such an objective is highly desirable. Research training can further such a goal. It can create an attitude that proves contagious. The attitude can be transmitted from the teacher to the student, or better yet, from student to student.

They, who are anxious for the spread of such an attitude, may appreciate research training for its effectiveness in developing good students and better citizens. An entire student body may be upgraded by admitting selected students to the research laboratories, by encouraging them in satisfying achievements, and by depending upon them to grasp a new outlook on education that they will pass along to other students. When more students complete research problems that represent a contribution, even though

small, to the advance of knowledge they will foster an increased thirst for education among their classmates.

The increased interest and imagination of students can be stimulated by aiding them in the realization that there remain many unsolved problems which form the basis of current research activity. Undergraduate courses should be continuously revised to permit the introduction of recent research results. We must guard the undergraduate from assuming that human knowledge is a completely developed and organized affair. Through research training we can demonstrate that the present knowledge is tentative and that it is being constantly revised and extended by research publications and review articles each year.

Guidance Difficult

Admittedly, such guidance for students is difficult, especially if they are free to choose their own problems. The research advisor must be careful to give the student freedom but, at the same time, attempt to guide the selection of problems which can be accommodated by resources available and which, preferably, have an opportunity for solution.

Even if it is the judgment of the advisor that the chances are small for a solution of the problem which a student selects, the student should be permitted to proceed if he is especially desirous to do so. Fortunately, under such circumstances, as with most types of research, unexpected problems and especially interesting new developments may be uncovered that will counterbalance the lack of a solution to the original undertaking.

Research training reaches its greatest effectiveness in the educational process on the graduate level because the student is more mature and, generally, is of above average ability. Further, he usually has demonstrated a desire for increased knowledge.

While the value of research is recognized, the interjection of a precautionary note might not be amiss. In our great enthusiasm for research as a tool used in the educational process, let us not create an illusion that research is a cure-all for the world's multitude of problems and troubles, nor lose sight of the fact that education by research training is essentially a means to assist the university or college achieve its proper goal of helping man know and understand more.

It is unfortunate that respect for research is more easily instilled than understanding. There are some segments of the public which tend to give unwarranted weight to the pronouncements of the research scientist in fields other than that on which he is expert. Among true scientists there are no final authorities. They know it is not the researcher but his evidence and his logic that count.

It is possible for a society to become too much absorbed in methods, even when they are scientific methods which lead to great technological progress. Education by research training does not necessarily equip men and women to set up ultimate values for society. It does prepare them to test, if they will, the values which evolve in the changing culture, to reject those which can be shown to be unworthy on the basis of man's knowledge and experience, to propose hypotheses which in their turn are tested, and thus to further the maintenance of an intelligent, critical attitude toward society.

Since research is a necessary and proper part of higher education it should be encouraged. It is the function of a university to create new knowledge, through basic research, as well as to disseminate it, through teaching. And the research activities of universities have been increasing at a rapid rate. Unfortunately, however, the emphasis has not been on basic research but rather on the applied, or hardware, type of project. This is understandable in a period of war where national security is involved and weapons research is vital. But the inventory of basic scientific discovery is rapidly being depleted by the drain of technological progress. It is important that the stockpile be replenished or we may become a

nation devoid of the means for further achievement.

Reasonable Relationship Important

However, while the desirability of fundamental research should be recognized, it should not be concluded that applied research is out of place in an academic institution. The university should also be concerned with the practical application of the new knowledge which it creates. By so doing its tremendous intellectual capacity can participate in the solution of society's problems. The important thing is to maintain a reasonable relationship between the two types of research.

In my opinion effective training can be accomplished in either basic or applied research, sponsored or unsponsored. Each kind has something of value to offer the student where the research objectives are compatible with the institution's program. The fact that some outside agency is supplying the funds to support a project does not mean necessarily that it is not a suitable matter for investigation by an academic institution.

In research training it would seem particularly appropriate that the student have some association with applied research. This is the kind of research predominant in industry, and since most engineering graduates are employed by industry, proper preparation of the student would involve some familiarity with this sort of endeavor.

The emphasis of the academic research program, however, should be on basic aspects because research which favors certain fields of knowledge at the expense of others, in which the goals are too limited, or which is tied to too strict a time schedule can tend to divert scholars in the colleges and universities from research which extends the boundaries of knowledge. The student who only follows a problem as outlined in detail will not acquire the proper attitude or aptitudes toward research. In such case he will gain experience only in the execution of the experiment, and to a certain extent in the analysis of the data, as the advisor usually assists in the evaluation to derive the fullest measure of information for the benefit of a review panel. If the purpose of education by research training is to increase knowledge and understanding, it is important that the research undertaken is devoted primarily to achieving that mission.

Conclusion

Without doubt, research properly conceived and conducted is an essential part of the college and university educational process. It yields benefits to both the institution and the student. It develops character, self-reliance, initiative, and enthusiasm. It results in a changed attitude of the student toward his studies, and enhances the value of his courses and of his use of the scientific literature.

In the years ahead, to do a truly effective educational job, increased emphasis must be placed on this kind of research. Accomplishment will be difficult, however, principally for financial reasons. Higher education, both public and private, now hard-pressed for funds, will experience a continuing fiscal struggle. We should not despair, however, but rather gain courage from the conviction that the mission in which we are engaged is worthwhile. Because of this we are confident that an understanding public will support it.

The Thermodynamic Method of Attack*

By A. K. OPPENHEIM

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Introduction

When I submitted the title of this paper, I was asked whether it is *exact*. I replied that it is, although I knew that it was not *complete*, since I had difficulties in defining the target for the attack and, consequently, left it unspecified. The method deals of course with engineering systems or engineering problems, but in my opinion, its main virtue is in *defining the system and specifying the problem.*

The first question, one may ask, is whether there exists such a thing as a "thermodynamic method"? In fact, I was not aware of it some twenty years ago when I started my studies of this subject. And one cannot find any evidence of a distinct method in the old classics which treat thermodynamics either as a branch of physics or chemistry (Planck (1), Guggenheim (2), Lewis and Randall (3)) or engineering (Goodenough (4), Schüle (5), Stodola (6), Barnard, Ellenwood and Hirschfeld (7)), or of philosophy (Planck (8), Bridgman (9)). The second logical question which suggests itself is then that even if such a method existed, whether we should teach it to our students or whether it would not be better to leave it for themselves to discover?

In the present dispute on these questions I would like to defend the positive. I shall, however, limit the scope of my proposition. I do not know whether the method should be described in our texts and, for that matter, I doubt whether it is at all possible to present it adequately in a book. But I am quite sure that it should be *emphasized* in our undergraduate courses known as Engineering Thermodynamics for Mechanical Engineers. In our College, as in many others, such a course is offered at the junior level in the mechanical engineering department. In my future remarks I shall therefore have this particular course in mind.

Why a Thermodynamic Method?

The necessity for emphasizing a method in an undergraduate course stems from my belief in the importance of adopting a unified point of view for presentation of any subject matter at this level. Irrespective of whether we favor approaching a subject from the general to the particular or from the particular to the general, the synthesis, in my opinion, is the key and the objective of university instruction.

When our students are first confronted with the problem of learning something about thermodynamics, they have been already acquainted with a number of engineering subjects such as graphics, manufacturing processes, measurement, engineering materials, and statics. They also have had a few courses in mathematics, physics, and chemistry. Introducing then a new subject at this stage, one should realize what most distinguishes thermodynamics from other branches of physics or engineering. The feature which always appealed most to me is that it provides a prescription on how to talk intelligently about things we do not know anything about. This notion is of course

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associated with the fact that in our undergraduate courses we emphasize the macroscopic point of view (as it has been indeed advocated at a similar discourse of this Society by Keenan (10) and Kaye (11) some time ago).

The approach to engineering analysis from a macroscopic point of view constitutes therefore the salient feature of the method.

What is the Method?

More specifically, the method consists of the proper treatment and arrangement of information on physical properties leading to the "engineering" definition of the system and formulation of the problem for the "thermodynamic" analysis.

At this time I must stress the fact that I am not trying to present anything original. In fact, I am sure, the method is well-known to all of you. Its application to thermodynamics was developed mostly by the M.I.T. group of Keenan. It was propounded by Boelter and his associates at our University, London and his group at Stanford University, and advocated by many others. It is described in many texts on engineering thermodynamics and related subjects such as those of Keenan (12), Lichty (13), Obert (14), Mooney (15), Shapiro (16) and Sweigert and Goglia (17). It is so fundamental and general in scope that, one may say, it is more characteristic of the whole class of problems of performance analyses of engineering systems. In this respect it is therefore closely associated with the design problem (the latter often involves a series of performance analyses; one being the inverse of the other) and, consequently, could be regarded as the most characteristic of the modern engineering practice.

What I would like to defend here is the viewpoint that it should be *properly introduced with a good deal of emphasis* at the junior course of engineering thermodynamics. The reason why this course is most appropriate for this purpose is the fact that it deals primarily with the most characteristic feature of a macroscopic analysis, namely, with the conservation principle.

In an engineering course one would like to, and should, tie-in the analysis with the engineering language: graphics. It is quite proper, therefore, to present the principle in this case by the use of a system diagram. The diagram should be considered much superior to the equation, and it is to be deplored that in so many texts and expositions of the fundamental features of thermodynamics the equations are often emphasized at the expense of the diagram (e.g. the so-called "general energy equation"). The student is thus sometimes led to the conclusion that, in order to know a subject, it is sufficient to know the equations, understand the symbols, and that the only effort needed to solve a problem is to substitute values into the algebraic formulas pulled out from the book or lecture notes. But even those who understand the importance of the diagram often skip the step between the engineering system and its diagrammatic representation.

What makes a collection of things an engineering system? The answer is obvious. A sufficient understanding so that its salient features could be represented *diagramatically* and its *boundaries* prescribed. What is then the most important aspect of the translation between the physical world and its engineering description which then forms the basis for the analysis? Obviously, the introduction of *idealizations* (or the so-called assumptions). This in reality can never be omitted, but in the instructions is often neglected. For the purpose of a given analysis we must specify that an element is rigid, a wall is impermeable, a substance is homogeneous. The results of the analysis represent then only the consequences of these idealizations and do not furnish a complete solution to an "engineering problem." In fact, I heard it stated many times, there is no such thing as a single solution to an engineering problem. But a properly specified system with a full set of idealizations

FIG. 1.

must lead to a single solution. Otherwise, the idealizations are not complete.

If it is agreed that these aspects should be properly emphasized, the last question is: How to do it?

How I Present the Method

One way of dealing with this situation is by means of the following method which I have used over a number of years, but which by no means is perfect and, of course, is open for criticism.

Utilizing the First Law as the excuse and general background for the topic, I present first the general features of applying a conservation principle. I use for illustation a variety of classes for which the existence of the principle can be postulated, such as money, mass, and (finally) energy. I break the procedure into three steps (Fig. 1):

Step 1. Define the system graphically and prescribe its boundaries.*

Step 2. Define (and indicate on the diagram) those elements of the class which cross system boundaries and those which are stored. (Note the use of zigzag arrows to denote scalar quantities.)

Step 3. Apply the conservation principle which, with the help of the diagram can be now stated as an equation:

$$\Sigma\Phi_{in} = \Sigma\Phi_{out} + \Sigma\Delta\Phi_{stored}$$

for same τ_0 and $\Delta\tau$

In the first step I describe the introduction of idealizations concerned with the system, such as the permeability of walls (with respect to value, mass or heat transfer as the case may be), the rigidity of the elements; and the relationship between the boundaries and the available information on one side, and the results of the analysis of the other. I emphasize then that, consequently, the boundaries should be determined on the basis of a careful *design* and I demonstrate how, by their proper prescription, the same physical system may be considered either as an open or a closed one, depending on whether the mass is allowed to cross system boundaries or not.

In the second step I emphasize the introduction of the idealizations concerned with the properties of the working substance; the relationship between their state when they cross system boundaries and their equilibrium state and the requirements associated with assigning values to their magnitudes which, as can be demonstrated, is always relative and involves therefore the use of the concept of datum. In the case of energies the usefulness becomes apparent of a distinction between those energies which can exist only when crossing system boundaries, such as work, heat and flow work, and those which can be only associated with mass, such as internal energy, potential energy, etc.

The last step involves only an accounting procedure. I emphasize the obvious

* The term "boundaries" is used here in the sense of the so-called "control surface" (see, e.g., Shapiro (16) or "Classical Thermodynamics" by J. H. Keenan, Notes for the Rumford Summer School of Thermodynamics, Massachusetts Institute of Technology, 1953). The boundaries define any identifiable volume of space. They may move and matter may cross them at one or more places. For the sake of convenience, however, those parts of the boundaries through which matter crosses should be considered fixed with respect to the observer.

fact that in order for the equality sign to be true, all the quantities must refer to the same initial time τ_0 and the same time interval $\Delta\tau$. This allows me to elucidate on the fact that the same physical system may be considered as a steady or non-steady flow system, depending on the selection of $\Delta\tau$. If $\Sigma\Delta\Phi_{stored}$ is zero the system is steady. In the case of mass this leads to the concept of the steady mass flow system; in the case of energy to the "steady energy" flow system. If, by a proper prescription of the boundaries, in both space and time, such a condition can be fulfilled, these notions may be often successfully exploited in the analysis.

At this time I like to inject some doubt into the students' minds as to whether our accounting has been complete or not. This stimulating, but often frustrating question leaves then a convenient opening for the future discussions of the First and Second Laws, the introduction of state functions, their relationships, state diagram, the concept of available energy, equilibrium, and even rate processes; in fact, the whole of macroscopic and even microscopic thermodynamics.

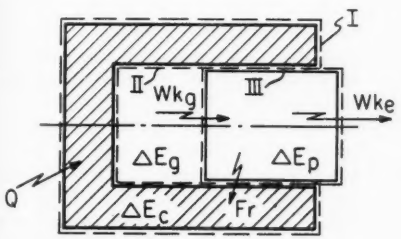
It should be noted that the method is based on the use of the diagram. As a logical consequence then of this feature, the well-known *sign convention* concerned with the direction of heat and work transfer *should be dispensed with from an "engineering" exposition of thermodynamics.* The use of a system diagram is, of course, well-known in engineering analysis (e.g. the free-body diagram of mechanics). However, for the purpose of a thermodynamic analysis its design and proper specification involve the consideration of more concepts than in any other case and, in my opinion, this fact should be clearly reflected in our instructions.

Examples

To illustrate the application of the method I shall use two examples: an elementary one and one more advanced.

The elementary example is taken from Obert's text (15), problem 6, page 46:

A piston-cylinder arrangement has a gas in the cylinder space. During a constant-pressure expansion to a larger volume, the work effects for the gas are 1.60 Btu, the heat added to the gas cylinder arrangement was 3.17 Btu, and the friction between the piston and cylinder wall amounted to 0.25 Btu. Determine the external useful work done by the process,



Given:

$Wk_g = 1.60$ Btu

$Q = 3.17$ Btu

$Fr = 0.25$ Btu

Find:

Wk_e

$\Delta E = \Delta E_g + \Delta E_c + \Delta E_p$

Syst. III: $Wk_e = Wk_g - Fr = 1.35$ Btu $\quad \Delta E_p = 0$

Syst. I: $Q = \Delta E + Wk_e$ $\quad \Delta E = \Delta E_g + \Delta E_c = 1.82$ Btu

FIG. 2.

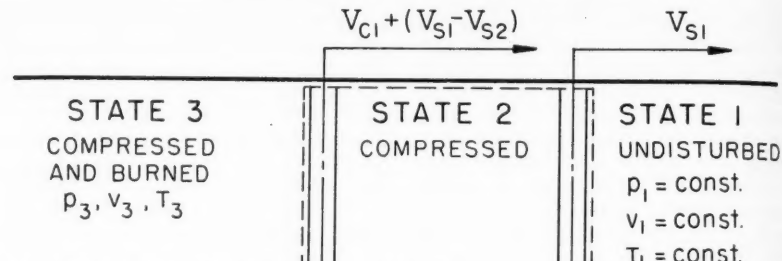


FIG. 3.

and the change in internal energy of the entire apparatus (gas, cylinder, piston).

As demonstrated in Figure 2, one must make a distinction between at least three systems for this simple problem. They are defined on the diagrams by boundaries I, II, III. The boundary between systems II and III is necessary because Wk_g is an energy term which can exist only while crossing a boundary. The distinction between systems III and I is needed to provide boundary for the friction term Fr. The problem is solved by applying the conservation principle to systems III and I. It should be noted that for system II the problem is undefined since not all the energy terms which cross its boundaries are specified.

The more advanced example may be derived from my work on the development and stability of detonation (18). The analysis is based on the notion that prior to the establishment of detonation, the system consists of, at least, a shock front and, following it, a combustion front. The idealized combustion system is presented schematically on a system diagram, Figure 3. The system is unsteady in both mass and state. However, the problem can be fully analyzed as a combination of two steady flow systems, namely that of the shock front and of the combustion front. According to my definition, both can be considered as steady since neither mass nor energy can be stored in such wave front systems. This, in fact, was the most powerful concept which allowed me to answer, in my opinion quite satisfactorily, such a question as: What are the minimum necessary requirements for the development and stability of detonation in a pipe? To my surprise I found, for instance, that both fronts must move at a higher velocity than their final one prior to the establishment of detonation (i.e. when the combustion front catches up with the shock front and the so-called Chapman-Jouquet state is achieved immediately behind the system) and that at the same time the intermediate pressure at state 2 must be much higher than the maximum pressure developed during the fully established detonation. Both these facts were later corroborated by experimental evidence.

Summary

In concluding I would like to stress that:

1. In our undergraduate instructions we should always attempt to present the

subject matter from a unified point of view, even at the expense of the scope.

2. In thermodynamics, this point of view should be associated with the proper definition of the system and its boundaries, both in space and in time.

3. Although the most useful illustration in thermodynamics is provided by the application of the first law, the method leading to the proper definition of the system and the formulation of the problem should be extended to the application of a conservation principle in general, and that of mass in particular (the exposition of the latter should precede the discussion of the first law) and it should be extended to the discussions of the second law and, in fact, used as a common denominator in presenting any topic especially in the junior course on this subject.

Acknowledgment

The ideas presented in this paper have been developed over a number of years of active association with both my students and colleagues. I would like to express my gratitude to all of them for helping me to formulate these ideas and especially to Professors A. L. London and R. A. Seban for many helpful discussions and suggestions.

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The Value of Research to the Education Program*

By J. C. WARNER

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My subject is one that has had much attention in the past and will continue to have in the years to come. It is a challenging subject because in some quarters it is believed that engineering faculties are not as research minded as they ought to be. As evidence, it was reported in the JOURNAL of this society as recently as last year that in about one-third of the institutions with ECPD accredited curricula, the administration gives less than moderate support to staff research, and in 10% was unfavorable to it.

Research as one of the primary goals of an institution of higher learning needs no defense; institutions worthy of the name have always felt an obligation to extend man's knowledge as well as to disseminate it. However, in addition to its significance in its own right, research stands in close relationship to education. It is my purpose today to examine carefully the relationship between research and education to understand it better and to see how it may be utilized to the fullest advantage of both.

I propose to consider in turn research in relation to the student, in relation to the faculty, and in relation to the curriculum.

As in any systematic discussion it is well to begin by defining the scope of the problem. I shall deal with professional education in engineering and science, the kind of education that aims to help the student learn to become not only a competent professional man but also a good citizen and one whose life is enriched by an understanding and an appreciation of our culture. Education to this end is one in which the student is helped to learn basic principles and the ability to apply them with well-ordered, analytical thinking to the problems he will meet as a professional man, as a citizen, and as a person. At the time his formal education is finished he is, in only a limited sense, a professional man. More realistically, the new graduate is a novice, with much to learn; indeed, in terms of the highest professional standards, he must go on learning all his life if he is to realize the attainment of which he is capable. Thus, an essential attribute of the education program which I am considering is that it prepares the graduate to go on learning and growing professionally on his own initiative through his whole life. Moreover, I am considering the *full* education program in engineering and science, which for many, perhaps most of the ablest students, involves graduate as well as undergraduate education.

Relation to the Student

Let us think first of research in relation to the student. How is the student helped to a genuine understanding of fundamental principles and the ability to apply them competently in problems which are new to him? I like Dr. Joel Hildebrand's way of answering this question in his remark that "ability to do something difficult is developed not just by hearing it expounded but by first-hand effort and practice. The role of the learner must be an active one. . . .

* Presented at the ECRC General Session, Annual Meeting of ASEE, Penn State University, June 22, 1955.

This principle is well understood in the realm of physical education, where muscular control is developed by performance, with repetition directed towards ever higher levels of difficulty and skill, and only incidentally by lectures and demonstrations. Athletes, including amateurs, are developed on the field, not on the bleachers." In our kind of education the engineering and science student is helped to an understanding of fundamental principles and to an ability to apply them professionally to new problems by using such principles again and again in problems that have elements of newness to him. The student should begin solving this kind of problem in his freshman year when it must be relatively simple; in later years problems become longer and take on the nature of projects; in the senior and graduate years they become theses. At all stages they have elements of research as far as the student is concerned; in the last stages they also are research from the standpoint of the profession.

Indeed, the high point, the focus of doctoral work, is on research, and this is in part for the reason that the scientist- or engineer-to-be does not really understand the basic principles in his field until he is able to apply them with competence and scholarly style to a problem of the length, depth, and significance associated with the doctoral dissertation. To the student, research is a means of learning and of demonstrating the depth of his understanding.

The principles that the engineering student uses in problem-solving are usually those of science; the method also involves engineering art as well. I am sure that the educational process is strengthened when engineering and science departments are closely knit together, as they are in a single college at my institution.

Research also serves the student's education in another way, by helping him learn how to go on learning. A good research problem usually carries the student out of his narrow field of specialization into areas that are quite new to him, where he has to learn to deal with situations without the benefit of organized courses. For example, one of my Ph.D. candidates in chemistry found that his research required him to measure the dielectric constant of slightly conducting solutions, and then, to advance his own problem in chemistry, he had to acquire competence in measurement techniques at radio frequencies. Before the problem was completed, I, too, had to become familiar with high frequency phenomena. In the same way a research problem in metallurgy required the use of high speed amplifiers and oscillographs. Doctor's theses in civil, electrical, and mechanical engineering often require the candidate to obtain more than an elementary understanding of the chemistry and metallurgy of the materials involved. And it is a commonplace that analytical research in engineering is based upon applied mathematics. Hence, when the student researcher has to acquire or extend his working knowledge in another field, he learns how to go on learning for himself and with a motivation that is not surpassed by any other technique of education.

Thus, while research is often considered to have a narrowing influence because it usually is concentrated upon a specific problem, I believe that research of the kind that should be undertaken in institutions of learning is more often an influence of the opposite kind. It helps to broaden the researcher because in this day of overlapping fields he has to learn and use principles, knowledge, and methods which have been developed in areas other than his own.

Relation to the Faculty

Research is equally important in relation to faculty. The good teacher is more than a competent practitioner of the engineering and science that is known today. He is intellectually curious and this leads him to be a student himself, one who is always seeking a broader and more profound understanding of his own field

and its relationship to other fields. In other words he is a researcher. He is eager to discover, impart, and defend new conceptions, new principles. By his research activity he keeps alive, keeps his viewpoint fresh, improves his perspective, and renews his enthusiasm for his subject.

In my own experience, for example, I have found relatively little enthusiasm for teaching the second law of thermodynamics, enthusiasm that motivates the student to a genuine understanding of the law, unless the teacher himself is making active use of it. And on the other hand one of my colleagues who is doing so in his researches is known for his clear, penetrating expositions of the law to his students. I will grant that there may be exceptions: really good teachers who do no research, and good researchers who are not good teachers, but I think they are relatively few. Think, for example, of the teachers you know who are somewhat less than mediocre in the classroom. Are they generally enthusiastic, successful researchers? I doubt it.

Moreover, there is nothing better to sharpen the teacher's own understanding of basic principles than having to defend his use of them to a reviewer of his paper, or to defend his results in a discussion with a peer who is critical.

It is a truism that a university is fundamentally a community of scholars, the faculty and student body. If an institution is to attain distinction it will be through the attainments of its faculty and the influence the faculty have on the students. Thus, a faculty of distinction is of first importance. Among the requisites for attracting and holding outstanding teachers, none is more vital than a scholarly environment, the opportunity to be closely associated with other scholars; this means significant, fundamental research. Thus, to keep a good faculty, as well as to keep a faculty alive, research is absolutely necessary.

The related fact that a top-ranking faculty brings distinction to an institution directly through its researches needs no elaboration.

If research is to be a real influence on faculty, it must be carried on by faculty themselves. Merely having research and teaching under the same roof does not necessarily mean that the one influences the other. Indeed, this is as false as the notion that by putting a book under the pillow at night one can absorb its contents painlessly. Research which is to have influence must be carried on by the teaching faculty, and this leads to a very real problem of balance. On the one hand research can have little influence on teaching if the professor is loaded with teaching and committee assignments to the point where he has little or no time available to engage in research. On the other hand if he is so engrossed in research that he undertakes scarcely any teaching, or, what may be more to the point, if he cannot put careful thought and planning into his teaching, again his research can have little influence on teaching.

Balance is required, and I suggest that there is an attainable, desirable kind of balance in which the mature professor actively participates in three kinds of activities: undergraduate teaching, graduate teaching, and research. Each kind of activity should be limited in extent so that ideally they can all be carried on in any one semester. If this leads to a total load that is too great, or one that is otherwise impractical, the pattern can be varied with undergraduate teaching in one semester, graduate teaching in another, and with varying emphasis on research.

Influence on the Curriculum

Now, let us consider how research may influence the curriculum. One way, perhaps the most direct one, is in facilitating the addition of new material. A professor carries on research in the area of his interest and helps to advance it. In doing so he becames familiar with what is really important in the new knowledge that is being discovered and brings this material into courses, usually in the first instance, at graduate level.

More often than not, the new material eventually finds its way into the undergraduate curricula. Current examples include solid state science and nuclear science, and I am sure that you all know other instances of this sequence: research, then graduate instruction, and finally undergraduate instruction.

Another way that research influences courses and curricula is in the selection of topics and relative emphasis given to them. In the years that science and engineering have been developing, many, many facts, laws, and principles have been discovered. Certainly not all of them can be or should be learned by the student. How does the educator choose among them? It is clear, certainly in the fields of engineering and science, that material is of importance according to whether it is basic and general, whether it applies in many situations instead of only in a few specialized ones. The teacher who is doing research is in a particularly strong position to know what is fundamental and worth emphasizing. To the extent that the principle is useful in extending knowledge, in solving new problems, it is a principle that certainly should be learned and understood by students. On the other hand, if it is a specialized application out at the end of a development instead of being suitable for the beginning of one, its urgency in education well may be questioned. Indeed, I think it is possible to look at a text book and tell by the choice of material and by the topics given emphasis whether the author is carrying on research and using general principles or whether he is merely a collector and retailer of information.

In what has preceded we have seen how research can contribute to the education of the student, to the quality of the faculty, and to the vigor of the curriculum. What kind of research should be carried on if the greatest useful influences are to be achieved? It seems clear that the research must be basic, must be pointed towards understanding with generality and with precision, in engineering as well as in science. The development of gadgets and hardware for their own sake is not a suitable goal. At a meeting of this same group a year ago President DuBridge of Caltech discussed the goals of research. He gave three good rules pertaining to research in a college of engineering:

1) Maintain a close tie with the basic sciences;
2) Stick to fundamentals; and
3) Be sure that the goals of sponsored and unsponsored research are the same.

Research that conforms to these rules is not only the kind of research that is needed to extend the knowledge of mankind. It is also the kind of research that makes the greatest contributions to an educational program in the ways that I have outlined.

The dangers inherent in contract research have been discussed by many educators: the possible loss of the researcher's independence or part of it; the submergence of teaching in an ocean of research; the financial dependence of an institution on contracts; the throttling of dissemination by security classification—and so on. An institution that is genuinely interested in education will do well to consider these dangers carefully in the light of its educational purpose. However, contract research properly controlled can be a tremendous asset.

Summary

In summary, research has a very important place in the education program. In order to contribute the greatest value to education, (1) it must be carried on by the teaching faculty and by the students, (2) it must be fundamental in character, (3) it must be maintained in appropriate balance with education and other activities.

Evaluation of Engineering Education*

By JOHN K. WOLFE

Manager, Advanced Degree Recruiting, General Electric Company

Following receipt of the interim report of the ASEE Committee on evaluation of engineering education, the General Electric Company circulated copies of this interim report to various units of the Company and to electric utility executives for comment. My remarks are in a large part compiled from the approximately one hundred replies which have been received. About sixty of these replies came from within the General Electric Company, principally from persons in the engineering function, and the other forty have been received from electrical utility executives. There was unanimous agreement that the principles embodied in this report represent a marked advance in engineering education.

The remarks here are intended to supplement the report rather than criticize. Some areas where we feel that special consideration is needed will be brought up and problems in these areas defined.

General Comments

The most frequently mentioned comment among the engineers surveyed was that one of the greatest shortcomings of the young engineer was the inability to express himself effectively. In light of this comment it is particularly gratifying to see the emphasis which your committee has placed on this matter. Your mention of the facility in expression both written and oral as a professional necessity puts this in both a utilitarian and humanistic aspect. Although your report lists this as a category of humanistic and social studies, our indication of comments from our engineers places the need of better expression above the social study in importance.

General Van Fleet, when asked to comment on his undergraduate impressions of President Eisenhower, emphasized Student Eisenhower's interest in English, resulting in the best ability of expression in his West Point graduating class. As well as giving the engineer instruction in proper English usage and grammar, we must impress him that his future, even in engineering, is closely related to his ability to express himself.

A deficiency of human relations understanding in new graduates has also been noted by our engineers. College engineering education like all other genuine education is of course practical. It is preparation. Its underlying principle is very simple. Young people are to be called upon later to carry on many activities. The purpose of the preparation is to bring it about so that those activities will be done better than they would have been if the preparation had not been given. School and college are both to be judged by practical standards.

From still another point of view, let us protest against the externalism of our teaching in order to get a socially adjusted individual. We teach too much about the machinery of life and far too little about life itself. We teach too much about the things which may be done and too little about what they are done for. As a people we have immense admiration for a man who builds a great library and profound disdain for a man who sits down quietly in the library to read a book, but what is he doing may

* Presented at the Annual Meeting of ASEE, Electrical Engineering Division, Penn State University, June 23, 1955.

we ask or what use is the reading of a book? What will it enable him to do? If one answers that he reads because reading a good book is a good human experience and that therefore it may be done not for the sake of something else, but for its own sake, practical men are sometimes mystified, but again let us protest that if reading is not good then the building of a library was not good and our benefactor is not good and nothing has been accomplished at all that he has given and done.

Our Company is in full agreement with your report in its recommendations that an engineering graduate should be educated, not merely trained, since upon completion of his undergraduate training, an engineer is merely beginning to learn. Colleges should therefore concentrate on providing the engineer with a broad base of training. This means a fundamental understanding of basic sciences and a humanities training that is closely coupled with the engineering training.

Creative Ability

Some persons to whom we sent the report on evaluation of engineering education felt that some mention should be made and something done to develop latent creative abilities of students. This is particularly needed in the better students and many of our people feel that we are tending to spend more time with the poor student in relation to the exceptional student and that if we did spend the same proportionate amount of time on the exceptional or better student then the overall result would be better. In reality we know less than we should about how the creative person functions in both science and in engineering but this is a problem which ought to deserve good study. All we really have been able to do so far is to provide an atmosphere in which a person can be creative. Many in the education field feel that the development of creative abilities stems all the way back to the students very early years and is involved primarily in developing a good curiosity.

Social Responsibilities

In our free competitive enterprise system, the product is "the thing." It is the very core of our whole economic and social structure. When a product is evolved which serves a useful purpose, it obviously contributes to our social and economic structure. The individual business venture in the free competitive enterprise system rises or falls depending upon its ability to furnish a product or service which the people desire and for which they are willing to spend some of their income. Thus it follows that the engineer and his contribution lie at the focal point of our social and economic progress.

A broad concept of engineering is in making useful to man the properties of matter and the sources of power in nature. There are many noble ideas to which a man may dedicate himself in this modern age, but I submit that this one of the engineer is among the finest. What greater practical service can a man perform for his fellows than to apply his specialized knowledge to the production of new and improved structures, machines, and manufactured products. The broader and more fundamental concept of the function of engineering is too easily overlooked in this technical age. We are so concerned with engineering in the specific that we are prone to forget its broader spiritual aspects.

A more subjective view point of engineering is found in the profession's own concept of its function. In the canons of ethics for the engineers adopted by the Engineers Council for Professional Development we are told that it is the engineer's duty "to interest himself in public welfare and to be ready to apply his special knowledge for the benefit of mankind." In a model adopted by the organization, we find the following, "When needed, my skill and knowledge shall be given without reservation for the public good. Special capacities bring the obligation to use them well in the service

of humanity and I accept the challenge that this implies."

The Better Student

As I mentioned somewhat earlier, some of our people feel that a greater differentiation of students should be made on the basis of ability and more opportunities should be provided for the gifted student to perform to the limit of his abilities. We are interested in the segment of the class which is capable of accelerated study. While it is true many of these people will go on to graduate school both in engineering and in science we feel that this should be encouraged and the depth of the engineer's training should be made as wide and as basic as possible.

More attention should be paid to reading and study habits. It is true that this begins often in secondary schools and even in primary schools. The student who is taught to read rapidly and comprehensively can double his productivity. We have often had the sad experience of people coming to work with us who read very slowly and really do not know how to study. This number is in the minority and we are happy that the unfortunate situation is definitely on the improvement.

The methods of attack utilized in solving overall engineering problems should be emphasized. Many times the particular engineer in a narrow field will know the specific methods of attacking problems in his own special field without knowing those overall principles which are used in all phases of engineering and science. This applies to the science field as well, since the integration of the engineer and the scientist is becoming more and more important in all of our operations.

We are in full agreement with your report that closer collaboration is needed between the science departments, physics, engineering, and mathematics. The studies of mathematics and engineering are particularly important and should be well co-ordinated so that the student studying engineering can make full use of all the mathematical tools available. Some schools have felt that the students who are not science majors should take only a part of the regular chemistry, physics, or mathematics courses, and in trying to cut down the time some watered-down courses in science have resulted. We object to a narrowing of the science curriculum in these simplified courses since we feel the engineers need thorough and basic science courses. Some comment has been made that the high mortality rates in these science courses decrease the number of graduate engineers available. We do not feel that this is necessarily the case. If a good science course is given and is presented well, we believe that the number of good engineers resulting from such courses will be essentially unchanged.

Although there is a possibility that engineering laboratory time, as well as science laboratory time, can be reduced in the curriculum, we should be careful not to eliminate laboratories for teaching basic experimental methods. Laboratories can be used as problem-solving experiences since they permit practical application of the theories. Many times the instructor will do laboratory demonstrations before the class or student rather than to let the student do his own demonstration and his own write up. The personal experience of the laboratory is much to be preferred over the laboratory demonstration.

Some of our people have pointed out that with the introduction of some of the proposed curriculum changes in this report, a motivation of the student may become a problem since the student will receive less actual engineering education early in his college training.

College Curriculum

One of the greatest controversies in the comments received from our people on this report was in this area and centered on the four versus five-year curriculum. In our own survey, a slight majority of our people favored the four year program, feeling that additional college

training was not always necessary and that widespread adoption of the five year course was unnecessary and would reduce the number of graduates available.

As mentioned earlier in this report, many of our people felt that the student should be taught effective presentation, both oral and written. In this connection an attempt should be made to integrate the study of English Composition with technical report writing. As many of your are aware, the writing of technical reports is a most important engineering function. Even though an engineer does an excellent technical job, if he cannot write a lucid report or make an effective oral presentation, little will be gained from this technical job. At a recent conference of professors of chemistry and chemical engineering, Dr. Joel Hildebrand of the University of California at Berkeley was asked the question as to how long he thought it would take to teach a scientist or an engineer good English, to which he replied, "about three generations." We have been aware of this fact and in our interviewing of people we find that the candidate's family background often reflects the ability of the student in English Composition and effective presentation. One area in which we feel college training could assist is by allowing the engineering student to make original write-ups of his experiments and not the sterotype form which has been quite prevalent. In this way he will be given the opportunity to express himself. Here, as in many other fields, practice is a great help.

Changes in Pre-College Training

Many of our people felt that some changes were in order so that colleges would be provided with more qualified high-school graduates to insure that an increasing number of capable people entered the engineering profession. Many of our people have the same impression as expressed in the report and we recognize the difficult position of the college to affect changes in the secondary school. It is always possible to get more engineers by lowering our academic standards, but we have always felt that this should not be done and that our standards should be raised continually at all levels in our educational system.

In addition, we believe that more emphasis should be placed on counselling and guidance in the high-schools. Aptitude and interest tests should be taken by all students and they should receive vocational guidance from qualified individuals. Even more important than this, I believe, there is a matter of inspiration from the individual teachers. In science we know this is an important factor. Many people will enter the profession because an individual high-school teacher has inspired the person to go ahead with the study. I am sure the same thing is true in engineering. But it may well be that it is in the first years of college where the inspiration and encouragement of the engineering professor is most effective.

Early attention should be paid to studying and reading habits, since these make such a profound impression upon the whole study course of the individual. A course in comprehensive reading might be made available to high-school students as an elective subject. But here again the student must realize the importance of taking these courses and their value to him throughout the rest of his life.

College Educational Methods

Many of our people pointed out that the similarity and the knowledge of the concepts of the basic engineering fields should be emphasized. Much of the tendency in recent years has been to emphasize differences in engineering education and how many different fields can be made of engineering, when in reality many of these refer back to the same principles and we lose more by this extreme diversity than we gain.

Some college men have told us that it is necessary for them to develop many intriguing fields which appeal to entering

students. Using a specific example, many schools are considering, and may be giving, a degree in nuclear engineering. We feel that the college can hardly give a man in four years enough basic training in both science and engineering to make him a good nuclear engineer. It is therefore better to give the basic training in physics and one of the engineering fields and then provide him with the means of learning the necessary nuclear engineering practice after he comes to work for the company. At the same time, we realize there is a recruiting problem for the colleges, because many of these engineering areas, particularly the new ones, have an appeal for the student and more people will go into this area if there is a particular fascination for them. We object to the large number of engineering fields, and we do feel that the emphasis should be on the same basic principles with a real minimum of variation of the basic course.

New Technology

I would like to talk for a few moments on the role of engineering and applied science for the future. In doing so, I should first like to review some of the broad trends in engineering. There have been a great many changes in engineering and in education in the past 30 years, and I can assure you that in engineering there will be a great many more in the next decade. Many doors in the long corridors of scientific progress, that once seemed so impregnably closed, now stand ajar. Some have been forced by wartime "crash" programs, and we in education and in industry are forging the keys to others in our laboratories. New technology is becoming available at a continually accelerated rate. Its effective application for the benefit of mankind is both an opportunity and a challenge. Extensive and adequate plans and preparations that will lead to and insure good management of our technological effort and resources are of utmost importance to all of us.

As one of the characteristics of our technological progress, Dr. James B. Conant has spoken of the "lowering of the degree of empiricism." The old-time inventor, often a brilliant example of the individual empiricist, has been largely replaced by teams of scientists and engineers. You might say that we attempt to synthesize a composite genius out of many specialists. The complexity of our problems and systems requires such joint efforts. Today, it is very infrequent that one engineer can know enough about all pertinent technology to fully exploit it in conceiving and creating new devices and new forms of devices. As the degree of empiricism in our science and engineering is lowered, the level of engineering competency must simultaneously be raised, through education, and in other ways.

The broad advances in technology still leave many unsolved problems in their wake requiring extraordinary effort and expenditure to overcome. For example, there is the barrier to substantial improvement in the machines used for the conversion of the energy of natural fuels to useful form because of the lack of adequate high-temperature, high-strength materials. In fact, the lack of adequate materials is more and more becoming the prime factor in the limitations to design improvement in much of our machinery. Hence, great effort and large sums of money are being expended by industry in an effort to push back this barrier.

It is very important to note at this point that the most significant contributions in new technology are those that touch off a chain reaction in product concept and design.

If I am to discuss the future role of engineering in industry, I should first say something about the economic background against which we must plot its ever-increasing stature. I shall not include in my comments any extensive references to the needs for defense. I believe that this has been sufficiently emphasized and this problem for our times was wonderfully summed up by Alfred North Whitehead as long ago as 1917 when he wrote: "In the conditions of modern life the role is

absolute, 'the race which does not value trained intelligence is doomed.' Not all your heroism, not all your social charm, not all your wit, not all your victories on land or sea, can move back the finger of fate. Today we maintain ourselves. Tomorrow science will have moved forward yet one more step, and there will be no appeal from the judgment which will then be pronounced on the uneducated."

Graduate Study

It was gratifying to learn of interest being developed toward graduate study in engineering since we feel this area is of increasing importance to our Company. As I have already mentioned in my discussion of new technology, areas of interest to us are requiring men trained in depth in science and engineering. We must not expect to find the men trained in depth coming out of school with a Bachelor's degree. In specific terms, the complex technology involved in much of the work being done in companies like General Electric actually calls for the greater experience and the training in depth possessed by men who hold a PhD or equivalent degree in mathematics or the basic sciences. Too often, however, we are still assigning this work to people whose qualifications are something less. This practice has produced some gallant struggles and —eventually—satisfactory results. But it has on occasion cost us dearly in time, lost motion, and quality of performance.

I believe that this same need exists, or soon will exist, throughout industry. The complexity and volume of the knowledge and understanding necessary to us dictate an urgent and continuing need for a relatively small number of people highly trained in very narrow disciplines.

Now, are these men good for anything else, and have we any channels for their development? It seems to me the answer to these questions is clear: They don't have to be anything else. It is true that this kind of gifted person will most often become dedicated to a narrow field of interest and his development will be in increasing depth. But this is exactly the man we need so badly at the frontiers of our complex and growing technologies. He is our main hope of assimilating technological change so it can be translated into useful forms. What we need to do is get him out there on the frontier, recognize his value, and keep him happy there, and pay careful attention to what he tells us. Also, from time to time we shall need to call him back to help us with peculiar phases of our current technological problems, and this two-way communication between him and us cannot but be helpful to both. In our actual experience these highly trained men develop in two directions. Some become more deeply engrossed in their own particular field and become outstanding specialists, while others broaden as they apply their knowledge to wide areas. The latter group can provide excellent management material since our operations are becoming more highly technical in nature and these men possess the training to make decisions.

What should we expect of young people coming to us with the Bachelor's degree? Remember they are the people who are going to work behind the frontier, translating technology into timely, useful goods and services. First and foremost, we should not expect them to be great experts in current practice and applications. The reasons why are clear: the volume and complexity of technology are much too great to be adequately presented in an undergraduate course, and the rate of change is too high. Overnight, today's detailed practice can be made obsolete by a single technological advance. What we must look for—what we must have for this job of utilizing technology—is young people who are versatile, and it would seem that there is only one sure way of getting them. They should be trained in breadth.

Off-Campus Research

Although it is recognized there are distinct advantages in requiring residence

for all graduate study, we must realize that there is going to be increasing pressure on universities to allow off-campus residence for graduate students. For example, there is little need for such a provision on the Penn State Campus since few research institutions or government laboratories are located in the vicinity. With other universities, however, there is increasing pressure to allow this type of graduate work. At one of the universities, for example, just outside of Washington, D. C., an extensive graduate and undergraduate program has been set up with the Armed Forces and government laboratories in the area. This type of study satisfies a real need. Educators will be required to make a decision on how to cope with this problem and since it is one that is likely to be with us for some time, it may be better to set the boundary conditions under which this graduate study may be allowed than outlaw it completely.

Academic Standards

There has been some industrial discussion, and I am sure university discussion, on the possibility of accrediting graduate schools in the same manner that under-graduate schools are accredited. I am not posing any solution to this problem at the present time, but pointing out, as I am sure you are already aware, that such accrediting would help many of us in evaluating graduate study at many of our universities.

As part of this problem, I would like to point out one aspect which has caused us some concern. This matter pertains to the change in status of the Master's degree. In many schools giving a Doctor's degree, the awarding of a Master's degree indicates that a candidate has been unsuccessful in his pursuit of doctoral study. He may, or may not, be a better student than an average Bachelor man, although he should have been to get accepted into graduate school. We feel that it is important that the universities maintain their standards just as high for Master's candidates as for any other degree so that the degree means the same thing at all universities. It is true that there is pressure on all graduate schools to accept more candidates to fill laboratory and teaching requirements. These efforts for college instructors should not be allowed to effect major changes in our academic standards.

College Notes

Lee L. Amidon, the head of the Mechanical Engineering Department at **South Dakota State College**, has been cited by the American Society of Mechanical Engineers for his service on the student branch of the Society. Amidon was a member of the student branch committee from 1950 to 1954, serving as chairman for two years. He was instrumental in starting several improvements in the work of student branches in the Midwest which are being considered for adoption by other regions.

Princeton University has announced graduate fellowships in an engineering curriculum of fundamental research in plastics which will lead to the degree of Master of Science in Engineering. The fellowships are particularly suited to chemical, electrical, and mechanical engineers and to chemists and physicists. Applicants must hold a Bachelor's degree in engineering or physical science from a recognized institution, and they must meet general admission requirements of the Princeton Graduate School.

Physics for Engineers*

By JOHN A. SAUER and DONALD E. HARDENBERGH †

There has been of late a great deal of discussion concerning the teaching of physics to engineering students. Under the auspices of the National Science Foundation, special conferences have been held in which both engineers and physicists have been assembled to consider calmly and collectively the general topic. Committees of various national societies such as the ASEE and the AAPT have also been investigating the problem for some time, as have also many local committees in individual colleges and universities.

Interest in this field together with the concomitant reexamination of the value of the general physics courses to the engineer has arisen largely because of the following situation.

In recent years numerous new developments have taken place in science and technology. To mention but a few, there are

1) The development of the whole field of nuclear energy with its manifest applications to both war and peace-time uses.

2) The development of aircraft and missiles with propulsion units and shapes that permit them to fly at many times the speed of sound.

3) The advent of the semi-conductor and transistor with their many uses in the fields of communications and computation.

These developments and others have led many engineering educators to feel that in their college and university training, future engineers should be given some training in the basic principles of atomic and modern physics. With this point of view there is very little dispute between physicists on the one hand and engineers on the other. In fact, in a steadily increasing number of institutions the general physics course, which has formerly dealt only with classical physics, has been expanded to include fundamental concepts of atomic and modern physics. For example, at the Pennsylvania State University all engineering students now take 12 credits of General Physics of which the last 3 credits are devoted to principles of atomic and nuclear physics. As another example, at a recent conference [1] where 18 different academic institutions were present, 7 reported that their engineering students received a course in atomic and modern physics of from 35 to 55 hours duration, and only 1 institution stated that no work at all in this field was given.

Where a dispute does appear to arise between most physicists and some engineers is in the time to be devoted to the so called classical physics. A few engineers feel that classical physics per se should be taken away from the physics department and some of the component parts of the subject be covered by the individual engineering departments which are most closely associated with that field. This is by no means a majority opinion among engineering educators but it is one that has been publicly expressed.[2]

* Presented at A.S.E.E. Allegheny Section Meeting, Bucknell University, April 29, 1955.

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[1] Conference on Mechanics in Engineering Education—Gould House, N.Y.U., January 1955, sponsored by National Science Foundation.

[2] J. D. Ryder—AIEE Winter Meeting, New York, 1955.

According to this plan the physics department would be alloted approximately one-half of its present number of credit hours and asked to use this time for a coverage of atomic and nuclear physics. This plan has two serious disadvantages.

1) It destroys the unity of scientific subject matter that exists in physics and will make it materially more difficult for the student to recognize that the principles developed in one branch of science are in many cases applicable to the problems of another.

A study of recent progress in applied science and technology indicates that the problems encountered frequently cross over many fields and that the engineer who is asked to solve such problems must have a deep, integrated and thorough knowledge of the basic principles of the various branches of physics. This point is well brought out in a report of the Grinter Committee [3] of the ASEE which states:

"... translation of new scientific developments into engineering practice will be facilitated by emphasizing unity in scientific subject matter. For example, there is a great deal of similarity both in conceptual understanding and in analytical methods among the generalizations of heat flow, mechanics of fluids, electromagnetic fields, and vibration theory. When a student understands these generalizations, he has gained a concept of systematic orderliness of many fields of science and engineering which enables him to approach the solution of problems in widely diverse fields, using the same analytical methods."

Thus any proposal to separately break up the component parts of physics and teach these component parts in separate courses in different departments would only cause a loss of integration and unity and thereby would less adequately prepare the students for meeting and solving new problems and new situations.

2) The second disadvantage of the Ryder proposal is that it fails to appreciate that developments in modern and solid state physics as well as developments in engineering science and technology depend to a great extent on a background and understanding of the principles and methods of classical mechanics and heat and of classical electricity and magnetism.

More "Classical" Physics

Both for follow-up courses in more advanced phases of physics or for preparation for solution of engineering problems, the student should have more, rather than less, of so-called "classical" physics. This does not mean more in the sense of additional topics—in fact the present number is already too great and should be reduced—but more in the sense of greater emphasis and time on the fundamental aspects of the subject. This is not only our opinion but is one of the expressed conclusions of one of the joint conferences of engineers and physicists sponsored by the National Science Foundation. We quote from their report [1]:

... the conference recommends that the basic physics course be strengthened by greater emphasis on fundamental classical principles and conservation laws, and by an introduction to wave and quantum concepts. Inclusion of these topics is an essential introduction to the later study of solid state or nuclear physics."

Setting aside the Ryder proposal, the question then remains: Can we strengthen and improve the training of undergraduate engineers so as to better fit them for the complex and difficult engineering problems that they are likely to encounter after graduation? All people concerned with this question seem more or less agreed that such problems require a solid basic training and that a strong, basic foundation is more important than subsequent proficiency in standardized techniques or computations of a specialized field. The Grinter report [3] already referred to, in speaking of the type of engineering problem likely to be encountered by the engineering graduate, states:

"Their solution, in turn, requires the

[3] Interim Report of the Committee on Evaluation of Engineering Education, A.S.E.E., June 15, 1954.

application of thoroughly understood fundamental principles and well ordered analytical thinking. . . ." Hence this report goes on to say that one of the instructional goals of engineering education should be to help the student "to learn to deal with new situations in terms of fundamental principles, on his own initiative, and with confidence and sound judgment."

It seems to us that there are a number of ways of improving the education of future engineering students so as to develop these traits. We propose the following steps, some of which have already been carried out by some individual colleges and universities, but many of which have not:

In the area of General Physics

a) Emphasize the fundamental principles of classical mechanics, thermodynamics, electricity and magnetism, and whenever and wherever possible show how the methods and techniques of one branch carry over into the others.

b) Illustrate the principles by use of examples, not taken by and large from the domain of engineering science, but wherever possible from the domain of physics. This is in accord with a stated conclusion of the joint conference[1] of physicists and engineers already referred to, viz.,

"It is also recommended that as far as possible, such particles as electrons, protons, and neutrons be used in the elementary physics course to illustrate general dynamical principles."

c) Omit extraneous material which does not have any direct bearing on the objective of developing an understanding of fundamental principles and conservation laws and above all else avoid racing through a large series of topics in survey-course fashion.

d) Use concepts of calculus wherever applicable not only as a means of time saving but also to foster facility in analytical computation so useful and necessary in most subsequent work.

e) Avoid giving laboratory instruction in the form of precise and definite orders and plan laboratory instruction so as to develop thought and inquiry.

f) Introduce basic concepts and principles of atomic and nuclear physics so as to provide the engineer with recently acquired scientific knowledge that he may well be called upon in the future to "translate into engineering practice".[3] This will also provide the student with an excellent opportunity to use and integrate the knowledge of methods and principles of the various branches of classical physics which he has just studied. It was concluded by the Conference on Mechanics[1] that in those institutions where 2 years are already devoted to general physics the additional material on modern physics could be included without requiring additional time. On the other hand, in those colleges and universities where only 1 year is now devoted to general physics, it was recommended that at least one additional semester be added to the general physics course.

In the area of subsequent engineering courses

a) For those engineering courses conventionally following the general physics course such as the first specific courses in mechanics, electricity, and thermodynamics, it should be kept in mind that understanding of the basic principles of the field is still a major goal of instruction. It should not be expected that sufficient mastery of these principles has already been attained in the preceding physics courses. Such mastery only comes after continued study. In this connection, it should be noted that even those students who major in physics rather than engineering are all required to take so-called "intermediate" courses in mechanics, electricity and magnetism, and thermodynamics. These courses still stress fundamental classical ideas and their applications to physics problems, and it is only after such courses have been mastered that the students are introduced to modern physics and quantum mechanics.

b) Engineering instructors should be aware of what has been covered in the general physics course and should re-emphasize the same fundamental laws and principles, but with emphasis on examples chosen largely from the engineering fields. In this connection, it would be an excellent idea for the individual engineering departments and the physics department to exchange instructors. In this way, subsequent correlation with a minimum of unnecessary repetition is assured. This system has recently been tried at Penn State with excellent results.

c) Just as for the general physics courses, the concepts of calculus should be used wherever practicable. It is the feeling of the writers that even in some institutions where the calculus course precedes the courses in statics, dynamics, electricity, and thermodynamics, full advantage of this fact is not taken and an opportunity to integrate the students' educational achievements is lost.

Conclusion

To summarize briefly, it is our opinion that the Physics course for engineers should be at least a 3 semester course and should place greatest emphasis on the development of the fundamental principles and conservation laws of classical physics. At the same time, an introductory treatment of the concepts and principles of atomic and modern physics should be included. Concepts of calculus should be used throughout the general physics course and all subsequent engineering courses. These subsequent engineering courses should also be taught not only as a first course in a more specialized branch of engineering science, but also as an added opportunity to provide the students with a greater degree of understanding of the fundamental principles of their field of study. Interchange of staff members between engineering department and physics department is advocated.

College Notes

The **New York University** College of Engineering Graduate Division will offer next spring the first university course on the use of scintillation counters as research tools. The course is intended principally for medical research staffs using radioactive tracers. Dr. Richard Stephenson, an Associate Professor at N.Y.U., will conduct the new course.

Dr. Paul P. Ewald, Thomas Potts Professor of Physics and head of the Physics Department at the **Polytechnic Institute of Brooklyn**, was recently elected an honorary member of the Societe Française de Mineralogie et de Cristallographie. Only eight men in the world today have been elected honorary members of this leading French mineralogical and crystallographical society.

The Institute of Statistics at **North Carolina State College** is sponsoring a seven day short course in statistical methods for research workers in industry and physical sciences starting February 12, 1956. This program is designed to acquaint research workers in industry and physical sciences with modern techniques of statistical analysis and experimental design. Guest lecturers will include W. G. Cochran, Johns Hopkins University, S. L. Crump, University of Rochester, and J. S. Hunter, American Cyanamid Co.

Engineering Education in Brazil

By EDWARD W. KIMBARK

Dean of Engineering, Seattle University

Brazil is the largest country of Latin America; it has about the same area as the United States but only about one-third the population. It is richly endowed with natural resources but is much less industrialized than the United States. The Brazilians want their industry to expand and it is, in fact, now expanding rapidly, thus requiring an increasing number of engineers. Brazilians admire the technical achievements of the United States; they buy many American automobiles and much American machinery, are entertained by American movies, and read American technical literature. Many American manufacturers have sales offices, assembly plants, and even some factories in Brazil. Americans, for their part, drink an enormous quantity of Brazilian coffee, thus completing the circuit of commercial interchange.

There has been also a considerable amount of "cultural interchange" between Brazil and the United States, one phase of which is that American professors have lectured and taught in Brazil; another, that Brazilian students and professors have studied in the United States. The writer recently returned to the United States from a stay of more than four years in Brazil, where he taught at a Brazilian engineering school (the I.T.A.), and thinks that his observations on engineering education in Brazil may interest members of the A.S.E.E.

There are (by November, 1954, data) 19 engineering schools functioning in Brazil. Of these, 5 are in the State of São Paulo, 4 in the State of Minas Gerias, 2 in the Federal District, 2 in the State of Pernambuco, and one in each of 6 other states. This distribution by states follows roughly the relative order of industrialization. Most of these schools are run by the states; a few are federal schools; a few are Catholic; and a few are private. All of them, however, receive federal subsidies and are controlled by federal legislation—a subject about which more will be said later. Two of the three branches of the Armed Forces (the Army and the Air Force) have their own technical schools of college level. The Navy, not having such a school of its own, sends some of its officers abroad for technical study.

A quantitative comparison of the extent of engineering education in Brazil and in the United States can be made in several ways, as tabulated below:

	Brazil	United States	Ratio
Population (millions) (1950)	52.6	150.7	0.35
Area (millions of sq. mi.)	3.29	3.02	1.09
Number of engineering schools (1954)	19	218	0.09
Number of engineering graduates (1952)	1,063	27,155	0.04
Number of engineers	16,000	400,000	0.04

These figures show that both the number of engineers and the rate of production of additional engineers are much smaller, in relation to the population, in Brazil than in the United States. This is natural in a country but little industrialized. However, the number of engineers in Brazil is only 40% of the number which would be required if Brazil should be content with a situation corresponding to that of the United States in 1890—a situation with which she does not wish to be content.

Civil Engineering Predominates

It is interesting to note the branches of engineering studied in Brazil. Of the 1063 graduates of 16 Brazilian engineering schools in 1952, 733 received diplomas in *civil engineering,* 89 in electrical engineering, 64 in civil and electrical engineering, 57 in electrical and mechanical engineering, 42 in industrial and mechanical engineering, 25 in industrial and chemical engineering, 19 in civil and mining engineering, 13 in industrial engineering, 9 in architectural engineering, 8 in mining engineering, and 4 in civil and industrial engineering. There were also a few graduates in aeronautical engineering, which were not included in the statistics quoted. The overwhelming predominance of civil engineering diplomas (82%, counting combination diplomas) is natural in a country having relatively little industry. Machinery can be imported, but buildings, roads, and dams must be built on the spot. Even the curricula other than civil include many more C.E. subjects than do the corresponding curricula in the U. S.

Engineering courses in Brazil are of five years' duration. The first two years are basic and more or less common to all curricula, the last three years being more specialized. There is almost no graduate study in engineering in Brazil. There are no evening courses and no cooperative courses, as we understand them, although a few engineering schools have summer surveying camps or require summer industrial work.

The biggest engineering schools are the National School of Engineering of the University of Brazil in Rio de Janeiro, the School of Engineering of Mackenzie University in São Paulo, and the Polytechnic School of the University of São Paulo. Each of these three schools has three or more different engineering curricula, and between them they furnish about half the number of engineers graduating each year. Many of the other engineering schools have only one curriculum apiece.

The National School of Engineering, owned by the federal government, appears to set the pattern for most of the other engineering schools.

The Polytechnic School of the University of São Paulo is generally considered to be the best Brazilian engineering school as well as one of the largest. One of its good features is that associated with it are two institutes to do testing, development, and research for industry and for the state of São Paulo and its municipalities, to maintain standards of measurement and to perform calibrations, to provide laboratory facilities and instruction for the School, and to conduct extension courses. One, the Electrotechnical Institute, performs these services in the electrical field; the other, the Institute of Technical Researches (I.P.T.), operates in several other fields, such as strength of materials, wood preservation, soil mechanics, and metallurgy. The University of Brazil also has an Electrotechnical Institute.

Mackenzie University is a part of Mackenzie Institute, which is unusual in that it combines on one campus in the city of São Paulo instruction from kindergarten through college. It is of especial interest to Americans because it was founded by Americans and has an American president and treasurer, who are Presbyterian missionaries, and an American board of trustees. There seems, however, not to be much American influence left in its engineering school, which has been obliged to conform to the pattern set by federal government regulations.

American influence on Brazilian engineering education in recent years has appeared mainly in the Technological Institute of Aeronautics (I.T.A.), run by the Ministry of Aeronautics of the Brazilian federal government and located in São José dos Campos, 60 miles from the city of São Paulo. This school is the first unit of the Technical Center of Aeronautics (C.T.A.), the second and much newer unit of which is a Research Institute of Aeronautics. The basic plan for the Center was formulated by an American professor, Richard H. Smith, about

ten years ago at the request of the Brazilian government. Professor Smith was later named as the first Reitor (academic head) of the I.T.A. The two subsequent Reitors have also been Americans, as have been several dozen of the professors. The I.T.A. has three curricula: aircraft, airways, and electronics. Most of the students are civilians.

Brazilian engineering schools, besides having the quantitative deficiencies already mentioned, generally suffer from the following defects: lack of autonomy, rigidity of curricula, high number of hours of class, poor attendance, too much emphasis on examinations, too little use of textbooks, inadequate laboratory apparatus, and too little contact between professors and students outside of class.

Lack of Autonomy is Basic Defect

The really basic defect, from which most of the others spring, is *lack of autonomy*. The curricula and the regulations on admissions, examinations, graduations, etc., are laid down by the Ministry of Education in Rio de Janeiro. Federal inspectors are located at each school to see that the regulations are followed. If a school should choose not to follow the regulations, it would not only lose its financial subsidy from the government but would soon lose its students, too. For the graduates of engineering schools cannot legally practice engineering until after their diplomas have been registered by the Ministry of Education, which registers only the diplomas of the schools which it has approved. Although, undoubtedly, the regulations were adopted for the purpose of maintaining standards of excellence, they have had the unfortunate effect of stifling improvement also, since the schools are not free to experiment with curricula and with educational methods. Professor Anísio Teixeira expressed the situation as follows: "Our activities are tied up in red tape, and we are all powerless to settle the questions which should be settled by our professional conscience because nowadays all of us, deans and professors alike, are merely appliers of laws and regulations." And, on the other hand, Dr. Maffei, Director of the I.P.T., gave as reason for the success of that Institute, "We have no regulations."

As a result of the regulations, *the curricula are too rigid.* All students in a given curriculum take the same subjects, in the same order. There are no elective subjects and no options to suit individual interests. There is no provision for some students to take a lighter program than others.

The number of contact hours are high (40 per week, it is said, at the Polytechnic School in São Paulo), thus leaving little time to study.

The *attendance* at lectures is voluntary and, probably as a result of the high number of scheduled contact hours and the fact that many students are working to earn part of their expenses, it is poor—perhaps 30% on the average. The attendance at practical classes (laboratories, inspection trips, etc.) is obligatory and is much better—perhaps 80%. Many Brazilian professors feel that obligatory attendance at all classes would be preferable to the present situation.

Because of the shortage of time for study while classes are in session and because of the great weight given to final examinations, the students tend to do most of their studying just before final examinations. And as a consequence of this habit, at many schools the methods of cheating during examinations have been highly developed.

There is little use of *textbooks* such as we are accustomed to. Some professors issue mimeographed notes. At many schools, notes made by students, after being submitted to the professor for correction, are mimeographed and distributed to the class. Sometimes these notes are sold by the student union. One professor expressed the conviction that if he should publish what he knew his services would no longer be needed. This feeling is undoubtedly shared by others, for rarely

does one find a textbook written by a Brazilian professor. In the bookstores, both American and European technical books are available, but the volume of sales is small, not being boosted by "adoptions." A very few of the most popular texts (such as Sears' *Physics* and Dawes' *Electrical Engineering*) are available in Portuguese translations, and many others, in Spanish editions, which are easily read by the Brazilians. However, nearly all Brazilian engineers read technical English.

Laboratory equipment, even in the best Brazilian schools, is generally inadequate. Much of it is antiquated. This situation is, undoubtedly, the result of insufficient financial resources.

The usual relationship between a Brazilian professor and his students is very formal. The students seldom, if ever, see the professor outside the classroom, and thus have no opportunity to obtain clarification of points they do not understand. Many of the professors discourage the students from asking questions during the class. In justice to the professors, it must be stated that most of them have only a part-time appointment and must supplement their low salaries by doing other work, often much more lucrative than their teaching. It should be said also that the official outlines of the courses contain so much material that the professor must hurry to cover even a reasonable part of it in class.

One often hears the graduates of Brazilian engineering schools criticized as being "asphalt engineers" who want to stay in the big cities and who do not like to get their hands dirty. This condition may be partly a result of inadequate laboratory work in school and partly a result of old Brazilian traditions. I do not believe that this criticism applies to all the schools. At least I know that, at the Electrical Engineering School of Itajubá, the students themselves have built and installed much of the laboratory equipment.

In addition to having the defects discussed above, the Brazilian engineering schools are said to be handicapped by the poor preparation given by the high schools. This has a familiar ring. However, the charge is probably true.

I hope that the Brazilians will not take offense at me for having listed these defects, of which Brazilian engineering professors are already well aware. Indeed, they have pointed out these faults in much stronger language than I, in statements quoted by Dr. Paulo Sá in his report on "The Teaching of Engineering in Brazil," published in 1954 by the Brazilian Standards Association (A.B.N.T.).

What To Do About It?

If the Brazilian professors are so keenly aware of these conditions, why don't they do something about it? Well, sweeping changes are not easily made, especially when laws have to be changed first. I believe, however, that the time is drawing near when reforms will be accomplished. The report just referred to is one sign of the increasing discontent of Brazilian engineering educators with the status quo.

A very potent factor in the reform which I believe is impending is the existence of the I.T.A., which has shown that engineering *can* be taught in Brazil in a way different from what it has been.

The I.T.A., being under the jurisdiction of the Ministry of Aeronautics and not the Ministry of Education, has, fortunately, avoided most of the defects which are apparent in the engineering schools controlled by the latter. The faculty of the I.T.A. has almost complete control over curricula and course content and is continually making changes as experience points to their advisability. Nearly all the professors are on full time, and both students and professors live on the campus; thus the students can become personally acquainted with their professors and are free to consult them in their offices at any time. There is a highly developed system of counseling to help the students with both academic and personal difficulties. Much emphasis is placed on current classes (problems,

laboratories, and quizzes) with consequent de-emphasis of final examinations. Cheating is practically non-existent. Attendance at all classes is required. Textbooks are widely used, and the laboratory equipment is adequate in most subjects. Thus the I.T.A., though not particularly impressive in comparison with many good engineering schools in the U. S., is outstanding among Brazilian schools. It has been warmly applauded in many newspapers and magazine articles, as well as in the report by Dr. Paulo Sá, already mentioned.

The primary reason for the character of the I.T.A. is not that it has had many American professors but rather that the group of Brazilians who founded it believed that it should be patterned after American engineering schools. And, after its founding, it attracted some Brazilian professors, such as Paulus Aulus Pompeia and Luiz Valente Boffi, who were dissatisfied with Brazilian engineering education and saw in the I.T.A. an opportunity for improving it. The influence of such professors on Brazilian engineering education will continue long after all the American professors have left the I.T.A.

Another factor which I believe will play an important part in improving engineering education in Brazil is that a good many young Brazilian teachers are studying for advanced degrees at American engineering schools. While I am writing, three Brazilians from the Electronics Division of the I.T.A. are on leave to study in the U. S., one at Cal Tech, one at Stanford, and one at M.I.T. I am confident that these men will learn much more than the subject matter of the specialties which they came to study: they will see how some of the best American engineering schools are organized and run. They will, I feel sure, put such information to good use after they return to their own country, helping to bring about the reforms which seem imminent.

College Notes

Illinois Institute of Technology has named Dr. Joseph C. Boyce, associate director of the Argonne National laboratory, as its new vice president of academic affairs and dean of its graduate school.

Alfred University, Alfred, New York, has established a graduate program leading to a doctor's degree of philosophy in ceramics at the State University of New York College of Ceramics at Alfred University.

A gift of $15,000 to the **Illinois Institute of Technology** for the development of its industrial design department was made recently by the Sears-Roebuck Foundation. The funds will be used to finance extensive re-equipping of some laboratories and workshops of the design school.

This fall, three engineering educators are beginning a period of studying industry, it operations and its needs, under DuPont's "Year-In-Industry" program. Participants this year are W. J. Richardson, Associate Professor, Industrial Engineering, Lehigh University; R. S. Rowe, Associate Professor of Civil Engineering, Princeton University; and J. K. Walkup, Professor and Head of the General Engineering Department, Iowa State College. The "Year-In-Industry" program is designed to bridge the gap between the college campus industry.

Birth of a Research Project*

By H. A. MIKE FLANAKIN

Highway Engineer, American Trucking Associations, Inc.

Last fall, Dean Sams said administrators had often wondered how research projects came into existence. He began baiting White Conner, Merle Baker, and me and we spoke back. Naturally, the fish with the biggest mouth got the bait and the hook along with it. Anyhow, he said, "You, Mike, are it."

Later I began to wonder just what I had undertaken. After all I'm not even a doctor of philosophy let alone an obstetrician. So what do I know of giving birth to anything. It occurred to me it might be profitable to give you a day from the life of a director of an engineering experiment station. You can see by the program that I am on leave from Louisiana State University where I served as acting director of the station there. But for the program one might think I were employed by the American Trucking Associations, Inc. I don't know just what the truckers will be asked to pay for that plug.

Let's suppose you are newly appointed director of the engineering experiment station at your university. You know what your personal salary is. The Dean has told you that. He has told you that you have a budget. He was about to go into detail when a call came from the President's office so he will explain it to you later. It is still later.

You are now on your own. You have met your secretary. You then sit down to look over your budget.

Funds have been budgeted for several research projects. You are listed as the director of each project. One is in chemical engineering. Two are in mechanical engineering. Another is in electronics. Finally, there is one problem in nuclear energy. You have some $3500 for each. This is to cover supplies, equipment and graduate assistants. Your own training has been in any field except chemical, electrical, mechanical or nuclear engineering. But that dosen't matter too much since you haven't any laboratories anyhow.

By now you decide you should find out how the university administration feels toward research. A study of the auditor's report discloses that 20 per cent of the university's budget is spent on research. That looks good indeed. A closer study shows that 18 per cent is spent for research in agriculture. The remaining 2 per cent is divided among medicine, chemistry, physics, speech, psychology, sociology, engineering, etc. Well you just don't fight with farmers do you? Congressman Morrill started the A and M colleges but somewhere along the line the M seems to have gotten lost.

Maybe you should talk with the President himself. You find him most receptive. He has never refused a budget request for engineering research when properly justified. He does need to be convinced that the engineering faculty is interested in research. This strikes you as odd. Then he explains. Most of the requests have been short, terse, and little more than a row of figures. When he asked for an interpretation the impatient engineer said: "Oh, skip the whole thing."

The President is amenable to permit reduction of teaching load as an inducement for research. He does want a bona

* Presented at the Annual Meeting of the Southeastern Section, American Society for Engineering Education at Knoxville, Tennessee on 15 April, 1955.

fide project to be established. He also wants the man's research time to be accounted for. It seems his neighbor (not an engineer nor an ag teacher) was listed on the payroll as half time teaching and half time research. The professor taught two 3-hour sections of the same subject. He spent 4 afternoons a week in his garden and sat with the children on Wednesdays so his wife could attend her bridge club. So the President looks with a jaundiced eye on "payroll" research men.

The President is not too happy over the sponsored research program but he will permit it. He will allow a faculty member to direct a sponsored project to the extent of 20 per cent overtime. The faculty member may be paid whatever the sponsor allows for the director. What about reducing the teaching load of some of the research minded faculty so that they may have time to bring in sponsored research projects? How about expanding research laboratories and equipment as an inducement for outside funds? Maybe you had best go get the project first and then he will talk to you about these things.

Now, you have just returned from a meeting of research directors of industry, government and universities. You learned how basic research ideas formerly came from scientists in central Europe. This fountain head was cut off by World War II and the Iron Curtain. Scientists everywhere are looking to American Universities to develop the basic research. Have they risen to the occasion?

You learned of the "Billion Dollar Package." You asked for a pocket full of money and were told it isn't quite that simple. You must bid for the money. The medium of exchange is qualified research men and laboratory equipment. The bill of sale is a proposal showing the sponsor what he will get for his money.

Perhaps you should call on the department heads in the college of engineering. What is the answer? How many of you have heard this:

"Get some money and suggest what I should do and I will consider it."

"Why don't the sponsors tell us what they want us to do and then give us the money?"

"Get the teaching load reduced first."

"Lab work! We can't even get a machinist."

"How can I do anything unless I have some equipment and staff?"

"We don't need research for our courses, just pay my instructors more."

"Why should I and my department do a lot of research just so you can publish a report!"

Key to the Problem

Maybe that last statement is the key to the problem. Surely engineering scientists are not indifferent to the value of research. So you ask for permission to talk to the individual faculty members. Sure enough, even though they have heavy teaching loads they are digging around and trying to find out why things happen.

One man had found out that the first movement in a steel eye beam loaded at the middle occurs in the unstiffened top flange over the support instead of the bottom flange directly below the load.

Another had found that a supersonic sound wave directed toward a moving object could be made to indicate the speed and direction of the object. And there were many others.

You asked why weren't these written up as research papers. Why! they weren't big enough to be called research projects. There was nothing *spectacular* about things of that nature. So what is spectacular about an apple falling out of a tree!

Now you know what your job as director of the engineering experiment station is. There are faculty members who want to do research. There are sponsors (industry, government and your own board of regents) willing and anxious to put money into research. Your job is to bring the two together. You just remember that birth comes about when the bashful boy is brought to the willing girl.

Now that you know what your job is, how do you do it? It isn't easy. The

first thing is to give up your own ideas of doing any research yourself. You want to make the faculty member and the sponsor attractive to each other. You might start out by adding a bit of glamor to the poor guy doing the research. You remember the money in your budget for the projects you were to direct and couldn't. Why not take that money and publish results of some of the research these men have done?

You decide to have no names on the report except the author's and of course the university. You soon discover that there is truly nothing more beautiful than a man's own name in print. Soon you have convinced the faculty member that you are not seeking to glorify yourself and you have won his confidence. You send copies of these papers to prospective sponsors—don't overlook your own university board and administrative staff. Of course, these sponsors may never read the papers. One day, however, a proposal will come through with the researcher as the project director. Then the sponsor will remember that he saw that name on a university bulletin sometime back so he must be a good man. He will be much more receptive to the proposal. You find that it doesn't stop here. While the sponsor and the faculty member—the boy and the girl—are important there is one other party who must be pleased. That is the university administration—the girl's papa and all of her brothers and sisters.

Let's take the case of Professor A. You knew he had been projecting around his laboratory for a long time. Maybe he had something he wanted to do. You called on him and asked—diplomatically, of course—why he hadn't published any papers. He was reticent to talk. You knew already that a former director of the station had placed his own name rather prominently on all experiment station bulletins. He also insisted on editing all papers. So you showed the professor the new format. As an example, you had placed his name in the author's spot. There were no other names on the format. You could see that he liked it. He said he'd think it over. A few days later he brought the complete manuscript for a good sized bulletin. Remember how pleased he was when you took the galley proof for him to proof-read. Then, of course, he received the first printed copy even before they had all been bound. The real pay off came when Professor A received a letter from an industry wanting 100 copies of his paper. From then on you were Professor A's favorite publisher and he brought material for many more bulletins.

Now that's not all. A publisher must be rather intimate with his authors. You learned that Professor A wanted to do some field investigations for material for revision of his text book. You knew he even planned to take sabbatical leave and finance the trip himself. You suggested that he make a research project out of it. Why it was unthinkable! The university would *never* consider such a thing! How did he know? Had the university ever been asked? Let's try it anyhow. Finally he agreed to write up a proposal. Maybe you did get a few rather flowery words into the professor's thoughts. In the meantime, you had discussed the proposal—informally, of course—with the Dean and your Engineering Research Committee. You had had coffee with the Vice-President and found out he rather liked the idea. One day you had business with the Dean of the Graduate School who was director ex-officio of all research. Quite by accident this matter came up and sounded good to him. Finally came the day when the proposal went to the Dean. He approved. Just to make sure there'd be no delays you *walked* the proposal through the chain of signatures needed and the project was set up. Even so Professor A was still skeptical. A week before he was to leave you handed him a voucher for his advance travel money. You also had him authorize the auditor to deposit his salary checks in his own bank while he was gone.

Professor A got his material for his revised book. You published four Engineering Experiment Station Bulletins. Your university got some good publicity. But most of all the engineering profession was enriched with some additional basic information.

Let's see how Professor B broke into the treasure chest of the National Science Foundation. Your congressman announced, in the press, that an appropriation would soon be forthcoming. It would be good for your university to be among the first grantees. Professor B had a full schedule but you had already learned that busy professors were more apt to tackle additional work than those with light schedules. Professor B was supervising a brilliant young graduate fellow who was on your payroll. You knew he had a basic problem in mind for a thesis and later a dissertation. So the three of you sat down and read the NSF rules and regulations carefully. You three then got busy. Preparation of the proposal turned out to be a major research project but you were determined it would be good. You checked with the head of Chemical Engineering to see that the apparatus would work. You asked for review by the head of Mechanical Engineering to see that the mechanical equipment was properly designed. You brought in the Electronics man to consider instrumentation. Finally, the three of you were satisfied you had a good proposal.

Then came the chain of signatures to the President's office. He was out of town so you left it with his administrative assistant. And you waited. You knew the President came back but still no word. Now you had already talked to Dr. Waterman and Dr. Klopsteg. You knew they liked the project because it would (1) add to the store of basic scientific knowledge, (2) assist a deserving young scientist to further his education, and (3) there was a shortage of applications from your area and they wanted to spread the money around.

Finally, after a month, you called the President's office. No the proposal had not been sent to the President for signature because the assistant just hadn't had time to review the proposal to see that it fulfilled all of the university and NSF mutual requirements. You blew your top but the proposal got approved and the project got under way.

Just one more example. One day the director of research for an industry called on you. He wanted to know what would happen to one of their new products when subjected to natural elements in your State. This was a rough one. You knew the young professor who should do the work. Trouble was it involved two departments. By devious ways including a cocktail party and dinner—paid for by industry, of course—you got the girl and all of her brothers and sisters to sit down with the boy and talk things over. Industry was reticent about publishing reports. This was overcome. The President's assistant wanted a patent protective clause. No patents were involved but he'd just read about the money Wisconsin makes from patents. Finally with a little greasing here, a little giving there, a contract was signed. Industry got its information; the young professor got a nice bonus; the university got an adequate amount for indirect costs; the experiment station got an additional 10 per cent for basic research and everyone prospered.

Review in Retrospect

Now you sit down and review in retrospect. It doesn't look as if you, the director of the engineering experiment station, have done anything. There is not a single report with your name on it. You have made no personal contribution to the fund of scientific knowledge. You have received no pay other than your regular salary. Yet and still you have perhaps the most gratified feeling of anyone. To you it is like the story the Bishop told about marriage. Here is a man (refer to Figure 1) and here is a

FIG. 1

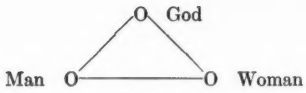

FIG. 2

woman. They love each other and get married. The bonds flow in two directions and the structure is not too stable.

Now here (refer to Figure 2) is a man who loves God. And here is a woman who loves God. The man and the woman love each other and form a union. This results in a triangular truss, which is the strongest structural shape there is.

You have been a party to such an arrangement. You have brought a faculty member and an interested sponsor together. They have a common interest in the university.

Additions have been made to the fund of scientific knowledge.

Your own life has been enriched as a byproduct. Your reward is good.

Program for Mid-Winter Drawing Division Meeting

January 26–27–28 Chicago, Illinois

Illinois Institute of Technology

Thursday, January 26. Executive Committee Dinner—6:30 p.m.

Friday, January 27. General Session—10–12 noon.

Papers by: E. G. Pare, "Technical Drawing for Science Majors." (IIT)

H. C. Messinides, "Design Consideration in Engineering Drawing." (Wilson Junior College)

L. M. Sahag, "The Relation Between Engineering Drawing and Machine Design." (Alabama Polytechnic Institute)

Luncheon and Business Meeting—12:15 p.m.

Inspection trip, *Chicago Tribune* plant—2 p.m.

Banquet and Address, Kungsholm—5:30–8:00 p.m.

Saturday, January 28. Open House, IIT Technical Drawing Department. General Session—10 a.m.

Papers by: J. Gerardi, "Should Colleges Teach Drafting Techniques?" (University of Detroit)

J. H. Bergen, "Simplified Drafting." (American Machine and Foundry Corp.)

A. S. Levens, "Introductory Nomography." (University of California)

Luncheon and optional field trip—12 noon.

The Young Engineering Teacher*

By PHILIP WEINBERG

Purdue University; Chairman, Comittee for Young Engineering Teachers

When I received an invitation to report to this eminent body about the activities of one of its newer committees, I could not help but recall my own initial experience with the Committee for Young Engineering Teachers. I had the pleasure of attending my first national A.S.E.E. meeting at Dartmouth in 1952. There I attended a YET session where there were but a dozen people present. This was not a very large group, considering that half of the gentlemen were on the program. I was amazed at the enthusiasm and perseverance that these young people possessed, for here were a few hardy souls imbued with an idea that one did not have to be within ten years of retirement before he was active in his professional society. During the five years in which the CYET, The Committee for Young Engineering Teachers, has been officially organized, it has been gratifying to see how this committee has grown steadily in activity and acceptance by the senior membership.

The Committee's origin stems back to 1949. The farsighted Society leadership, having sensed the lack of participation in Society affairs by its younger members, empowered an interim committee headed by Professor F. L. Schwartz to study the problem. The committee was requested to explore areas of interest and organize sessions, conferences, and other activities specifically for younger members of A.S.E.E. This group prepared a report which was published in the JOURNAL in 1950, and on its recommendations, the Committee for Young Engineering Teachers was established.

Broadly the aims of the Committee are:

(1) To help the young engineering teacher orient himself into his dual profession, that of engineering and education; and

(2) To provide a mechanism by which YETs might be recognized and utilized so that they might be of service to engineering education.

The Committee encourages its sectional representatives to stimulate activities among younger people by such devices as institutional seminars, luncheon meetings, sessions at sectional and national meetings, and the paper contest. In this manner, attention is focused on the problems of the younger teacher, and this in turn assists the YET in visualizing his own problems.

Problems of Importance

When the CYET was organized, some thoughts were expressed that such a committee would have little value because the young engineering teacher did not have problems sufficiently unique to warrant special attention. A moment of reflection would show that there are a number of specific problems which should be of considerable importance to the YET. One purpose of this Committee has been to focus attention on these problems.

The Young Engineering Teacher should be concerned with

1. His professional education as a teacher

The new teacher has to solve such problems as development of effective teaching

*Presented at the General Session, Annual Meeting of ASEE, Penn State University, June 20, 1955.

style, fresh methods, means of evaluating the student, and counseling techniques.

2. Obtaining industrial experience

The YET needs to develop insight in the subject matter he is teaching.

3. Pursuing formal education and higher academic degrees

Every young man who wishes to grow in his profession must seek new knowledge. Pressure by administrations compels him to pursue advanced degrees.

4. Institutional policies and procedures

He has an interest in opportunities for advancement, financial remuneration, security, and problems of this type.

5. His professional development

In addition to the other facets of his development, he might be concerned with the publication of articles and textbooks and the methods of obtaining research contracts.

6. Social development

The YET has probably been up to his ears in intense specialization prior to his entry into teaching. He is usually just beginning to develop his personal and community relationships.

All of these factors present significant problems to the Young Engineering Teacher. By pointing to these situations, the CYET has attempted to satisfy one of its broad objectives, the orientation of the YET into his profession.

A second major aim of the Committee is that of providing service to engineering education. The CYET has assisted the Society in its Membership Campaigns during the past two years. It has established local contacts at most engineering schools through its sectional sub-chairmen. Most important, it has provided a mechanism through which younger members have had an opportunity to participate in Society affairs. In this way, young engineering teachers displaying promise have been recognized and tapped for service in many of the Society's functions. Many young men who have cut their teeth in serving the CYET have since diffused into other committees of the Society. Prior to the establishment of the CYET, it was difficult for younger men to be spotted for service early in their careers. As a further attempt to provide a means of expression, it is hoped that the recent appearance of *YET-itudes* in the JOURNAL will provide an open forum for the enthusiastic and uninhibited ideas of younger people.

I have attempted with these few remarks to give you a general picture of this Committee and its scope. Detailed information about the YETs appears in a very interesting article written by Professor Robert Howe which appeared in the JOURNAL in November 1954. The title of this article is "YET's? What's That?"

Education As a Teacher

I have previously mentioned six areas of development that should be of interest to the Young Engineering Teacher. The first point mentioned was the YET's concern for his professional education as a teacher. I would like to discuss this point further. We in engineering education have made little attempt to develop teachers of engineering. It has been tacitly assumed that all that is necessary for a man to become a teacher is to acquire the necessary academic preparation and then to put the man into a classroom. When the young man selects college teaching as a profession today, he finds practically nothing in the form of organized planning to help prepare him for this work. Engineering educators should consider some type of organized program designed exclusively for the development of the engineering teacher.

I suggest that the ECAC, Relations with Industry, and Young Engineering Teachers Committees study the feasibility of organizing an annual summer workshop in which a young teacher who has been teaching a short while, say less than five years, will have an opportunity to prepare for his profession. Perhaps one summer period on the subject of educational theory and subsequent summers in specific industrial assignments would help broaden his own perspective and deepen

his appreciation for the engineer he is nurturing. It would be conceivable that an inducement to attend the workshop might be a quarter's credit toward the Ph.D., if he doesn't already possess it, and a fellowship with some nominal remuneration to compensate for lost income. In normal times, perhaps such inducements would not be necessary, but at present, it is almost a prerequisite.

Would such a program be of value? There are indications that the number of available teachers with experience, advanced academic training, and a desire for teaching are not keeping up with growing enrollments. Some signs of a growing shortage are:

1. That the number of Ph.D.'s in engineering granted annually have not increased in the last four years, as may be noted in the *Journal Yearbook* for 1955. There is little likelihood that increases in the future will keep up with the demands for these people by industry and education. The educational institutions are running well behind industry in attracting these men.

2. It seems reasonable to assume that fewer people are selecting teaching as a permanent profession because of attractive opportunities elsewhere. This statement would be verified by most department heads. Consequently many institutions will have to rely on secondary personnel such as graduate students and part-time people.

A trained cadre of young teachers, perhaps obligated to conduct institutional seminars, can cause a diffusion of ideas and techniques which will help bolster educational qualities, this at a time when opposite forces are tending to lower these same standards.

Such a program would most certainly appeal to the young teacher. It would be highly beneficial to the engineering schools since it would place emphasis on an area that in the past has been sorely neglected, that of developing college teachers.

In summary, let us note that the sound development of engineering education for the future depends on the younger men of today. Their sound development will reflect itself into our colleges for many years to come. It is this major consideration to which the Committee for Young Engineering Teachers is devoted.

In the News

W. W. Gridorieff, chairman of the University Relations Division of the Oak Ridge Institute of Nuclear Studies, was recently elected as the first permanent executive secretary of the **American Nuclear Society.** Mr. Gridorieff succeeds Professor William M. Breazeale of Pennsylvania State University, who had acted as interim executive secretary since the Society's founding in January, 1955.

Dean R. C. Ernst of the University of Louisville recently announced a gift from Mr. and Mrs. William S. Speed of $450,000 to the **Speed Scientific School** towards the construction of a Civil and Electrical Engineering building. The growth of the Speed Scientific School since its establishment in 1925 has been closely related to the generosity of the Speed family.

Blurred Borders of Physics and Engineering*

By J. H. VAN VLECK

Dean of Engineering and Applied Physics, Harvard University

The only instruction received concerning the subject matter of this paper was that it should have at least some relation to the Conference on Electricity and Magnetism in Engineering Education which was held at Lehigh in February, 1955. Instead of emphasizing what was said or done, I am going rather to focus my attention on what was not said or not done, and stress that there was a salutary freedom from excessive dogmatism in the conclusions. I must confess that I approached the conference with some trepidation, as with a carefully arranged equal representation of engineers and physicists I was afraid that the meeting might savor of a knock-down and drag-out battle between two factions, reminiscent of a jurisdictional dispute between two labor unions, and equally pointless. Actually I was happy to discover that on the whole the union-card aspects were singularly absent.

The final paragraph of the report of the conference which carries the heading "cooperation to meet local situations" appeals to me as particularly significant. I reproduce it here in full, as it leads to the main thesis of the present paper.

"The conference recognizes that the jurisdictions for the various functions implied in its recommendations must vary from one institution to another as indicated by local conditions. It strongly urges sustained contacts between the departments of physics and electrical engineering in each institution by such means as frequent conferences and exchanges of teachers and personnel on research projects. The understanding gained by such contacts should make it possible for faculties to develop optimum engineering programs with their local facilities."

Cooperation in Wartime

This proposition that the physicist and electrical engineer can benefit greatly by frequent contacts and close cooperation strikes a most responsive note in me in view of my experience at the Radio Research Laboratory of Harvard during the war. Here electrical engineers and physicists were gathered together to work on a practical engineering problem, the jamming of the enemy radar. It was clearly demonstrated that physicists and engineers each have something to learn from the other, and that it is futile to talk of one discipline as being the superior of the two. It is today a cardinal fact and the substance of many reports on engineering education, that science is involved in far more complicated ways in modern engineering devices than in times past. In this connection I cannot do better than quote from the report of a panel headed by Vannevar Bush which was concerned specifically with engineering problems at Harvard but nevertheless contains much sagacious general philosophy on the interplay of science and engineering.

"The borderline between the engineer and the applied scientist is becoming dimmed. It has never been clear cut. . . . Engineers, those who are in the forefront of advance, are becoming more entitled to be recognized as scientists in their own right. Applied scientists, under the pressure of war and its aftermath, have often become accomplished engineers as well."

* Presented at the Annual Meeting of ASEE, Penn State University, before a joint meeting of the Electrical and Physics Sections with the American Association of Physics Teachers, June 21, 1955.

At the Radio Research Laboratory, and at the closely allied Radiation Laboratory of Massachusetts Institute of Technology, which was concerned with radar itself rather than its counter-measures, I learned that the leaders in the research and development program immediately at hand could be men who had achieved distinction either as engineers or physicists. The Harvard laboratory, incidentally, was staffed dominantly by engineers, and that at Massachusetts Institute of Technology by physicists, but in either institution there was close integration of the two disciplines. I learned that what one might call good physical intuition and real engineering know-how were, to be sure, to a certain extent complementary, but nevertheless were usually merely semantically different definitions or specifications of the same attribute; a man who had one quality generally had the other.

Cooperation in Peacetime

These remarks which I have made concerning the benefits of liaison between physics and engineering have so far been centered around the war effort, but in my opinion they apply equally well to educational efforts in peacetime. It is sad but true that in many colleges and universities there is not today the same infiltration of physicists and engineers in a common effort that prevailed in the war laboratories. The fact that they are usually located in different buildings and often in different schools, and belong to different faculties accentuates the difficulties of liaison, but nevertheless it remains that close cooperation and mutual understanding is a highly desirable goal. If a physics department or engineering division feels that it has nothing to learn from the other, the chances are that something is the matter with at least one of the two—most likely the one that thinks it has nothing to learn.

It perhaps will seem rather shocking to suggest that sometimes an engineer might try giving a course in physics, or vice-versa. Whether this is practicable depends on local conditions, the breadth of a man's interest, and especially his ability as a teacher. I was gratified to see that one of the headings of the report is labeled "Need for Experimentation in Curricula" and makes explicit the wish that "no action taken by it (the Lehigh conference) be interpreted as discouraging experimentation by the universities in altering the content of its courses, or in changing the location of courses within departments."

Electricity is probably the branch of physics and engineering where these two disciplines overlap and dovetail more intimately than in any of the other standard fields. My personal experience in teaching the junior or senior course in electricity is confined to the war years when the regular staff was on other assignments, but my observations there convinced me that the basic course in circuit analysis, i.e., the one beyond the usual preview in an introductory physics course, is a sort of triple-point where mathematics, physics, and engineering meet. No one of the three disciplines is involved in very high echelons, but the union of the three presents a liaison which can well be baffling to the student who tends to compartmentalize his knowledge. In mathematics, nothing more recondite is involved than complex algebra and differential equations with constant coefficients. In physics the primary concepts are of inductance, resistance and capacity, along with impressed EMF. The engineering aspects involving resonance, transients, tunable circuits and the like are probably more intuitive to the present radio-minded American youth than they were thirty years ago. Nevertheless the fusion of the three disciplines, the transition from the complex plane of the mathematician to the tuned circuits of the real world appears as a very subtle *tour de force* to the beginning student, in which drill and guidance are necessary for the man of average ability, and the services of a good drill-master or expositor are invaluable. His quality as a

teacher is far more important than the department in which he is housed.

I may give two examples of men from my own institution particularly qualified to teach across the board. Our junior course in electromagnetic theory at Harvard is given by R. V. Pound, who is ostensibly a physicist, but who won the B. J. Thompson Memorial award prize of the I.R.E. in 1948 for his frequency stabilizer. For the other example I go back to the time when I was a graduate student in 1920 and took a course in thermodynamics with Harvey Davis, later to become president of Stevens Institute of Technology. This course, though it pointed towards engineering applications, brought out with remarkable clarity the physical meaning of such concepts as entropy, reversibility, and the like, and consequently furnished a remarkable educational opportunity for any physics student.

Albert Einstein

No one will deny that outstanding physicists differ widely in how much flair they have for the world of engineering and affairs. This fact is illustrated by two men whom America has lost in the last few months, and who rank with the greatest physicists of all time—Albert Einstein and Enrico Fermi. No one can mention their names this year without paying them tribute. I have had the good fortune to have known both of them, though my acquaintance with Einstein was mainly at the time of the Solvay Congress of 1930. Some of Einstein's discoveries, notably the relation $E = mc^2$ and the photoelectric equation, have had revolutionary repercussions on modern engineering science. As Dean Freund aptly said at the annual meeting of the Steel Founders' Society of America in Chicago, March 15 of this year, "$E = mc^2$ has importantly influenced each one of 2,500,000,000 people who live in the world, with the possible exception of 30,000 Eskimos and a scattering of bushmen in the interior of Australia." Still I do not think anyone would be tempted to classify Einstein as an engineer. In fact, research in the later period of his life was primarily mathematical and cosmological in character.

Enrico Fermi

The case of Fermi is different. It is true that most of his career was that of a physicist, but not to recognize his contributions to engineering in atomic power would be as unimaginative and unappreciative as not to accept him as a great American on the ground that he was born in Italy and spent roughly the first half of his years of scientific productivity there. To be sure, Fermi did not pretend to be a man of affairs, or pound the table, and there were some to whom his soft-spoken Italian manner did not carry conviction. However, there was one engineer, a leading figure in the Hanford project, who listened to Fermi with the greatest care and particularly valued his counsel. That man is now president of du Pont.

Anyone who heard the paper presented by Zinn (the present director of the Argonne Laboratory) at the special ceremonial session of the American Physical Society held in honor of Fermi last April was shown in no uncertain terms that his work in the design and construction of the first atomic pile under the west stands of Stagg Field was one of the great engineering achievements of all time. One can argue *ad infinitum* as to definitions of what constitutes engineering and what constitutes physics, but by any rational measure, this pile was a masterpiece of engineering. Earlier in this program, Dean Bewley mentioned that a physicist is a man who seeks to understand nature and an engineer is one who seeks to utilize it; an atomic pile is pretty clearly an instrument of the latter category. It is also said that a physicist analyzes, an engineer synthesizes; the careful addition of successive bits of uranium to (or rather subtraction of cadmium from) the pile until it became self-sustaining is an example *par excellence* of synthesis. Another criterion for

separating the engineer from the physicist is that the former is concerned with problems of design; and the first atomic pile is certainly an epochal example of pilot-plant design. The design problem was a particularly baffling one, not only because of the novelty and complexity of the project, but also because the constants involved were inadequately known, and because any error in design might have tragic consequences, both in terms of human life and the direction of the scientific war effort. For instance, it was not known how the various cross sections and other constants connected with neutron capture and diffusion varied with temperature, especially at the high temperatures which should be associated with a self-sustaining pile. Consequently, even the sign of the temperature coefficient of the reactivity of the pile was not known. This was most disconcerting, for if the temperature coefficient were positive, the heat developed by the onset of the chain process might make the reaction become more and more violent, not so much so that the pile would become a bomb, but enough for it to explode or disintegrate, and cease to be useful. This uncertainty Fermi circumvented by inserting electric heating coils in place of some of the uranium rods, and analyzing the effect on the neutron flux when these coils were heated. In this way it was found that the temperature coefficient of the reactivity was negative and the thermal changes would not lead to a catastrophe. In this, and in many other ways, Fermi's atomic pile was a monument of careful planning. His later contributions to the Los Alamos program and to the problems connected with the plutonium plant at Hanford were also notable.

It has been argued in certain quarters that because physicists are these days so much concerned with problems of nuclear physics, they have wandered too far afield from classical physics and from the design problems of the engineer and that consequently the courses given by the physics department for the engineer should be confined to atomic structure and similar subjects. However, I think a very good case could be made to the contrary—that the large pieces of apparatus involved in nuclear physics have made the physicist design-conscious and made him more conversant with problems of mechanical and electrical engineering than in the past. The Chicago synchrocyclotron was Fermi's concern in the period following the war, when he could devote his attention to pure research. An example of one of the design problems involved in this huge machine was the moving from one place to another around the cyclotron track of the target to be irradiated by the beam coming out of the machine—a problem in some ways like rotating a telescope from one setting to another, but with the complication that the instrument was located in the radiation-danger zone, and so could not be touched during the moving processes. Fermi himself built the car or truck shown in Figure 1. It is a little hard to find a name for it. Among physicists it has come to be known as "Fermi's trolley," a rather inappropriate designation inasmuch as no power was applied to it through wires. Instead, for power, it used induction effects from the magnetic field of the cyclotron itself. In other words, the trolley carried only, so to speak, the armature of a motor. Also it needed no rails, because its wheels fitted the rim of the lower magnet pole. By remote control a safely located push-button experimenter could start or stop the car at will. Even the wheels were constructed of lucite, to avoid eddy currents. In her excellent book,* Mrs. Fermi in discussing her husband's work on the Chicago cyclotron says, "Enrico built a small gadget for the large gadget—'Fermi's trolley'—a platform of lucite mounted on four wheels, looking as if they came from an erector set. . . . It looks very neat except for a sloppy joint of wires, conspicuous in front of the platform.

* Laura Fermi, "Atoms in the Family," University of Chicago Press, 1954, pp. 262–263.

FIG. 1. "Fermi's Trolley."

A man's nature never changes. Enrico has always given attention to performance and disregarded appearance." That the problem in design was not an elementary one is shown by the fact that two other physicists tried to copy the idea without success—at least initially—for in one case the apparatus burned up from *rf* induction effects; a scientist of another cyclotron laboratory once ruefully remarked, "In my city we do not have Fermi's trolley, only 'A Streetcar Named Desire'" (then playing at one of the theaters).

Examples like this show, I think, pretty clearly that apparatus of nuclear research, because of its size, complexity, or high power, can involve real problems of design in electrical and mechanical engineering. Complicated drawings, specifications, etc., are found in physics laboratories today which are a far cry from the simpler pieces of apparatus of the turn of the century, which Goudsmit aptly characterizes as the old string and sealing-wax days. When Harvard awarded an honorary degree to Fermi, President Conant referred to him as the one man in America who was a whole physics department in himself, an allusion to the fact that he was both theoretical and experimental, and from time to time even gave the most elementary course in physics at the University of Chicago as well as advanced graduate lectures. The citation might well have said that Fermi covered many segments of an engineering school as well.

Thomas Alva Edison

So far I have discussed a man generally classed as a physicist, but who has made notable contributions as an engineer.

I shall devote the remainder of my time to the converse case, of a man who is generally considered to be an engineer or inventor, but who has made an outstanding contribution to physics. The example I take here is Thomas A. Edison.* Although one usually thinks of him in connection with the electric light, gramaphone, and other similar projects, his discovery of the Edison effect, which is essentially the phenomenon of thermionic emission, as early as 1883 was a cardinal advance in physics. The rectification properties associated with the negative charge of the electron were latently visible in his experiments. The significance of his observations was not properly appreciated until after the discovery of the electron by J. J. Thomson in 1896. Had the physicists of the 1880's followed up Edison's observations with the zeal that they merited, we might have had the thermionic valve, radio, and the like, a quarter of a century earlier.

It is interesting to compare some of the points of resemblance and diversity between our two great engineer-physicists and physicist-engineers, Fermi and Edison. Both men possessed a flair for the practical as well as a curiosity for how things work. Edison's practical talent, to be sure, was much more on the engineering than the economic side; as he was a poor businessman. With his 1093 patents, the largest number ever given to one man, one is apt to think of the Wizard of Menlo Park as interested only in problems of application. It is true that economic and other pressures kept him working dominantly on the applied side, but he had a real curiosity for understanding nature as well as utilizing it. Edison himself said, "I was a poor manufacturer. As soon as I have finished a machine I'm anxious to take it apart again in order to conduct an experiment. That's an expensive mania for a manufacturer. My ambition is to be able to work without regard to expense. What I mean is that if I want to give up a whole month of my time and that of my establishment to finding out *why* one form of a carbon filament is better than another, I want to do it without having to think of the cost. That galls me. I want none of the rich man's toys. I want no horses or yachts—I have no time for them. What I want is a perfect worshop." It seems sad indeed that Edison could not have had the independence of a modern research laboratory, be it industrial, governmental, or academic.

Another point of similarity of Fermi and Edison is that they pioneered in new fields, and did the unorthodox. When Edison termed his first firm one in electrical engineering it was regarded as almost heresy from the traditional standpoint. He said, "Everything is so new that each step is in the dark. I have to make the dynamos, the lamps, the conductors, and a thousand details the world never hears of." Fermi could have said the same thing in 1942 when he tried to chart the passage of neutrons through carbon and uranium.

There is one respect in which the chronicles of discoveries of Fermi and Edison are different from each other and from what one might at first thought expect. With the currently prevalent idea that interest in science and technology is a comparatively new development, one might conjecture that Edison's discoveries would have gone more or less unheralded, and had little immediate repercussion on the financial world, and that the reverse would be true of Fermi's findings. Actually, Edison's pioneer work attracted wide notoriety. Some three thousand people were transported in special trains to see early demonstrations of the electric light. Each improvement immediately depressed gas stocks, and on one occasion there was virtually a panic on the London stock exchange. On the other hand, the first chain reaction on

* The information on Edison's career in this paper is culled mainly from "American Science and Invention," by Mitchell Wilson; Simon and Schuster, New York, p. 286 ff.

December 2, 1942 went virtually unnoticed except in highly classified echelons. Not even Fermi's wife knew what was taking place. Of course, the initial secrecy of the advent of atomic power was connected with war time security, but in Edison's case there is, I believe, another angle that should be mentioned. He had to advertise to get money for research, and his only source of income was through technological successes. His early invention of an improved stock market ticker was, for example, probably more a matter of expediency than deliberate choice of a field of endeavor, for financial transactions were not Edison's first love. At any rate, even at the age of thirty he apparently did not realize that a lump-sum payment of a given amount of principal could be capitalized and so was preferable to the same total payment distributed over a period of years. One can amuse oneself conjecturing what would happen if some one appeared on the scientific horizon today who gave promise of discoveries of originality, novelty, and importance comparable with those of Edison. Think of the competition of large industries to bid for him on their research staffs, or of universities to get him to head a government-financed research contract. Instead, Edison had to do his research the hard way, as an individual entrepreneur.

Some Conclusions

Perhaps I appear to have digressed too far from the theme of educational curricula in discussing Fermi and Edison as two prime examples of the engineer-physicist and physicist-engineer. However, I believe that study of their biographies is not without relevance to our educational pattern. For one thing, comparison of their careers shows the importance of advanced training under modern conditions. Edison had practically no schooling, even of the elementary variety, whereas Fermi had a Ph.D. It is doubtful whether someone even of Edison's genius could make his mark in equal degree today without further training, but fortunately there are available today many financial aids which had no counterparts fifty years ago. Of course, there is always the worry, expressed in many quarters, whether even with the financial avenues open, science and engineering attracts all those with native ability in it. Conceivably Edison, had he lived today, might have passed up higher education and ended up a super-technician in some laboratory rather than exploiting his full genius, for the frontiers of discovery are certainly much less accessible to the unschooled than they were fifty years ago.

Perhaps the greatest moral to be gained from surveying the careers of these two men is how futile it is to try and delineate ironclad borders between physics and engineering. This is true in educational curricula as well as research, and the greater the cooperation between the two groups, the greater progress will be. Had the import of the Edison effect been realized in 1883 we might have had the era of the vacuum tube much earlier than we did. This is not an indictment of our research physicists of Edison's time, however, because there were practically none in America at that time. On the other hand, recently the transistor was born as the brain child of the theoretical physicist rather than as a sheer empiricism like Edison's early tube discoveries. The contrast again illustrates the difference between research conditions then and now.

In closing, I must caution that I do not want to give the impression that there is no difference between an engineering and a physics temperament. There certainly is. The fact that after the war Fermi went into cyclotron research dealing with mesons rather than becoming a big wheel in the atomic power industry, as he could undoubtedly have done, shows clearly that he was at heart a pure scientist. It is idle speculation whether, with a different background and training, Edison might have developed differently—it is fortunate that his career was as it was. One thing is clear—despite different nuances in temperament—engineers and

physicists of the first rank can traverse the frontiers between the two disciplines when occasion demands, with highly beneficial results.

Of course, the objection might be raised that the two figures whom I have discussed are not typical. The average faculty member is no Fermi or Edison, much less so the students. However, we must set our sights high, and look to our leaders for inspiration, guidance, and example—otherwise we may be mired in the morass of mediocrity and routine.

In preparing this manuscript the author has benefited from correspondence with Dr. Herbert Anderson, whom he wishes to thank. The photograph reproduced in Fig. 1, was taken by Mr. Stephen Lewellyn.

Mid-Winter Meeting of Cooperative Drawing Division

January 9 and 10, 1956 — The University of Akron

The two day session will include discussions of "Ford Method to Encourage Use of Co-ops," "Home Reading for the Co-op During His Work Period," "The Value of My Co-op Experience to My Present Employment," "Are Co-op Schools Selling the Co-op Plan Short?" and "Professional Attitude and the Engineer." A Workshop Session will center around pertinent problems in cooperative education. Arrangements are being made by Mr. Earle Hamlen, Vice Chairman of the Cooperative Education Division, and Associate Professor of Coordination, University of Akron.

Annual General Assembly Engineers Joint Council

January 26 and 27, 1956 — Hotel Statler, New York City

Major features of the program will be problems of utilizing engineering manpower, the growth pattern of the engineer, and the engineering aspects of the Hoover Commission reports.

Problems in Communication in the Engineering Science Curriculum*

By WARREN E. WILSON

George Westinghouse Professor of Engineering Education,
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Dean Christensen's request that an attempt be made to fit the subject of this paper into the general theme of the summer school, namely, "Communication: Experiment and Experience," seemed to present very great difficulty at the time. However, as the end of the academic year approached, it became more and more apparent that many of the problems associated with the Engineering Science curriculum were really basically problems in communication. It is necessary, however, to acquaint you with the objectives of this curriculum and describe it briefly before presenting for your attention some of the problems in communication which have confronted us and in several cases still lack a solution.

The Engineering Science curriculum was established a little over two years ago on our campus and during the current year, had enrolled in it fourteen Juniors and nineteen Sophomores. This curriculum was designed specifically to educate students who wish to enter the fields of research, development and other creative aspects of engineering. The curriculum is broader than that of the specified professional curricula and the student is given work in all major engineering sciences with special emphasis on fundamentals and the relationship between the various sciences. This curriculum is more demanding than the others and provides an excellent training for industry as well as preparation for graduate work. Students in this curriculum must maintain at least a 1.5 average during their college careers.

The curriculum is characterized by the following features:

(a) The freshman year is the same as that of all other engineering curricula. This permits students to transfer from any other engineering curriculum at the end of the freshman year without difficulty. Since, however, the curriculum is designed only for the better students, and especially for those who expect to do graduate work, transfers are only permitted provided that the student's grade point average is 2.0 or better.

(b) A course in mathematics is given each semester throughout the four years.

(c) An average of one non-technical course is provided each semester throughout the four years.

(d) One foreign language, German, is required for a two semester period and more languages may be taken among the twelve credits of non-technical electives during the last two years.

(e) In addition to a course in Modern Physics, this curriculum provides a laboratory course in Atomic Physics and a course in Optics. Other physics courses can be taken as technical electives during the last two years.

(f) Eighteen credits of technical electives are provided during the last two years. Of these eighteen credits, nine credits must be scheduled in an approved sequence in one of the well-defined engineering fields.

* Presented at the ASEE English Division Summer School, The Pennsylvania State University, June 24, 1955.

The curriculum was established under the auspices of a committee appointed by Dean Walker and is governed by a curriculum committee composed of several members of the original group and others in addition. The Engineering Science Committee formulates policies to be followed in the administration of this course of study. Administratively, there is no actual department of Engineering Science but the writer acts as department head at the present time. The teaching load is carried by members of the departments offering the various courses. The procedure for the selection of these teachers has been quite simple and direct. Each department is informed of the courses which must be taught and is requested to nominate the best teachers available. The teachers are not under any compulsion to teach these courses and may elect not to do so if they so desire. In addition to the acting department head's usual duties, he also has the obligation of carrying on studies in Engineering Education and finds it most convenient to use this curriculum as an experimental medium.

Four Lines of Communication

Within this curriculum, the lines of communication may be described quite simply and are four in number. The first of these is between the curriculum committee and the department head. The second is between the department head and the teachers. The third is between the department head and the students and the fourth is between the teachers and the students. The number and orientation of these lines differ in no essential way from those of the ordinary department if one notes that the committee on the curriculum simply represents the faculty of the college as a whole. However, there is a marked difference in several cases in so far as the ease and adequacy of communication is concerned.

As suggested above, there are significant differences associated with the four lines of communication compared with those of the ordinary curriculum. We shall first consider the mechanics of these lines and then investigate in detail problems that have been associated with each.

The first line of communication, that between the committee and the department head, is similar to that which ordinarily exists between the faculty as a whole and the department head and the dean and the department head. In actual practice, it differs slightly in that the department head is chairman of the committee and finds himself, therefore, in the position of taking the initiative and guiding the curriculum but feeling restrained to call upon the committee for advice and counsel when new situations requiring policy decisions are involved.

The second line of communication, that between the administration and the teachers, differs in two important respects from the usual. In the first place, the teachers are not members of the department of Engineering Science, hence the common relationship of department head and staff member does not exist. On the other hand, these teachers are all voluntary teachers and are enthusiastic about this experimental program and prone to communicate their ideas more readily and extensively than is commonly the case.

Communication between teachers and administration and among the teachers was fostered by three meetings during the year. All teachers concerned with the curriculum were in attendance and discussed at considerable length topics such as duplication of course material, better cooperation and coordination in the teaching of the courses, methods of grading this highly selected group of students and other most pertinent topics.

Communication between the administration and students differs from that of the other departments on this campus particularly due to the fact that the number of students concerned is very small whereas in the regular departments, the number is so large that no department head is able to communicate directly with his students.

Communication between teachers and students once again differs somewhat from

that in the conventional curricula. First, due to the fact that the group is small; secondly, due to the fact that some of the teachers meet with the students in more than one course and hence, get to know them very well and, thirdly, due to the fact that students and faculty both are extremely interested in this experimental program and tend to communicate much more readily than is ordinarily the case.

As has been indicated above, lines of communication are more open and accessible than is frequently true in standard curricula. However, we have been confronted with one extremely difficult problem of communication which pervades the situation at all levels. This problem is associated with the need to communicate the original concept of the founding committee to the department head, the staff and the students. The author feels that he, as the department head, has understood this concept which, incidentally, has been discussed in the literature of Engineering Education for many years. In fact, it can be traced back at least as far as the Wickenden Report in the late 20's. It will be assumed, therefore, that the communication from the original committee to the department head was successful. However, some of the present committee members were not members of the original committee and it was necessary to be certain that the original idea was conveyed to them. The next communication problem in this area was to make certain that the teachers understood thoroughly the features to be incorporated in the courses which would differentiate them from the conventional courses. A comparable problem exists in conveying basic concepts of the curriculum to the level of the students. This is particularly difficult since they had access to no such ideas in high school or in the freshman year.

Illustrative Situations

In order to illustrate the situations which have arisen, one problem will be discussed in connection with each line of communication. First of these is with reference to communication between the department head and the committee. An early problem of such a type is associated with the need for courses in design in the curriculum. Some members of the present committee felt that such a course is absolutely essential for any engineer. Others did not agree. It has been necessary, therefore, to refer to the members of the original committee in seeking a solution. To date, we have not really been successful in this quest. The major difficulty seems to lie in the fact that each member of the committee, who is himself a department head, visualizes clearly the needs of students in his own curriculum. It has proven impossible to project from the present undergraduate situation to that which will obtain fifteen years hence when these students have become active in their professions. Those who visualize their activities at that time attempt to imagine what they might need comparable to a present day design course. Those who feel that no conventional design course is needed find it very difficult to communicate to the other members of the committee their concept of an engineer who will design but has had no such course in design.

One of the most difficult problems is communication between administration and teachers. A fundamental concept associated with the curriculum is that the students must acquire knowledge of basic principles and that we must foster their ability to apply these basic principles to the solution of completely new, in fact we may say unique, problems. The conventional method of teaching in engineering colleges runs counter to this concept although many teachers will not admit it. Inspection of any standard text in engineering courses reveals that the practice is to present tools of analysis and to afford a great deal of practice in their use by working large numbers of quite similar problems. Quizzes and examinations regularly contain problems not very different from those in the textbook which were worked as homework. It has been difficult, therefore, to

convey the concept that the student should master the basic principles and develop facility in working problems which he has never seen before. Some progress was made in the direction of solving this problem by conducting a two-hour oral examination for each of the fourteen Juniors. Twenty-three faculty members conducted these examinations. Each student had at least four examiners in addition to the speaker. A number of the staff who thoroughly understand the objectives of the curriculum interrogated the students in such a manner that both staff members and students must necessarily have obtained a better appreciation of the objectives of the curriculum.

Communication with the students, particularly by the department head has been centered around an attempt to convey two basic ideas. First of these is the concept of Engineering Research which is of course almost unknown to students at the sophomore and junior level. The second idea is that of learning basic concepts and developing skill in applying them to new situations.

Progress was made in the communication of the idea of Engineering Research to the students through the medium of a weekly seminar. Research engineers and scientists talked to the students on such occasions and visits were made to several laboratories on the campus.

Equal success cannot be claimed in communicating the most important feature of the curriculum, a mastery of fundamentals. As stated previously, the oral examination for the Juniors undoubtedly helped those students. Nothing comparable was done for the Sophomores and attempts will be made next year, especially in the seminar, to assist the next year's Juniors in this manner. A new text and different staff for the courses in mechanics during the sophomore year are important factors in an attempt to assist in the orientation of next year's Sophomores to the desired viewpoint.

The students have raised several questions which it has been very difficult to answer and only partial solutions to the problem have been attained. For example, they are concerned with what future employers will think of this curriculum and what graduate schools may think of it. The most practical answer turned out to be the ease with which even sophomores in the curriculum obtained very good positions for the summer.

There is one area in which the open lines of communication have been most effective. This is associated with those difficulties which arise when students and teachers do not see eye-to-eye. On several occasions, students have complained either at the pace at which the course was progressing or duplication of subject matter. In each case, the simple procedure of making a telephone call and getting the interested instructors together has resulted in an effective solution to the problem. This happy situation is derived from the fact that the author can devote much of his time to the occupation of "watch dog of the curriculum." This might not be a practical solution in the case of a curriculum enrolling hundreds of students. However, it may point the way toward improvement in other curricula suggesting that open lines of communication between students, teachers and administrators are highly desirable.

An investigation which it is proposed to carry out next year is closely associated with problems in communication. It is prompted by a strong feeling that quizzes and examinations, which are obviously media of communication, function also as very powerful teaching tools. The experiment will be directed toward determining the effect of two different types of examinations on the students' progress in a course of study. One group of students, the control, will pursue a standard course with the usual quizzes and examinations of the routine problem type. The other group will study the same material but will be quizzed and examined on basic concepts and applications to new situations. The effect on the mastery of the material and development of skill in its use will be evaluated at the end of the semester by a comprehensive examination

given at the same time to both groups. The governing hypothesis in this study is that students will make a real effort to attain that which is expected of them as indicated in quiz and examination questions.

Summary

In summary and conclusion, one may truthfully say that problems of communication have played a major role in the organization and administration of the Engineering Science curriculum and give promise of continuing to be in the forefront for some time to come. Efforts will be made to solve the problems as they arise and it is hoped that solutions obtained may be helpful to others undertaking the establishment of similar curricula.

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Our Output Problem*

By EDWARD J. RISING

Assistant Professor in Mechanical Engineering, Kansas State College

Engineering education in the United States has a challenge to meet. Our output has fallen off nearly fifty per cent in the last four years.[1] Because of small entering classes in 1951–52 (ten per cent under the average since 1947 [1]), our production will stay low for the next two years. Industry clamors for more engineers; technical society publications view the present engineering personnel shortage with alarm. A recent article by M. H. Trytten appearing in *Mechanical Engineering* compared engineering education in the United States and in Russia.[2] This article presented data that indicates that Russia is graduating engineers approximately twice as fast as the United States. The purpose of this paper is to show some of the ways the output of engineering schools can be increased without sacrificing quality or lowering standards in any way.

Increasing the Output

Perhaps the biggest problem engineering education faces today is one of quantity rather than of quality. By and large, industry seems satisfied with the quality of our output. This is shown by the energy and money they spend each year trying to recruit engineering graduates. We of the engineering education profession can point with pride to our satisfied customers. Each year they come back in larger numbers, with more elaborate brochures pointing out the advantages of their companies. Our seniors get expense-paid trips to plants and home offices. The red carpet is rolled out for the engineering graduate of today, and it appears to be out to stay.

Often we read in our journals about the "shortage of engineers." Authors vie with one another in extrapolating figures to 1960 or 1975. But consider for a moment that the students we will graduate in 1960 are finishing their senior year in high school. What are we doing to make the needs of industry and society for engineers known to these people? What are we doing to publicize the advantages of an engineering career? For the most part, nothing!

Let us consider our output problem in a systematic manner. Our engineering background gives a logical approach through the functional relationship among output, input, and efficiency. We know that if we wish to increase the *output*, we must first increase the *input* and *efficiency*.

Increase the Input

In September, our graduating classes of 1961 are going to be starting their senior year in high school. For them, this next year is going to be the year of decision. If we are going to have more engineers in 1961 we must have more freshmen in 1957. There is, then, no alternative to going into our high schools and attracting these seniors.

If we could attract a large portion of this group of high school students, we would find that many would not meet the standards of any accredited engineering

*Awarded Honorable Mention in the ASEE Young Engineering Teachers Paper Contest of 1955.

[1] ———, JOURNAL OF ENGINEERING EDUCATION, Vol. 44, No. 6, Feb. 54, pp. 4.

[2] Trytten, M. H., "Engineering Education in Russia," *Mechanical Engineering*, Vol. 76, No. 11, Nov. 54, pp. 882.

school. Of those who could meet the standards, some would not make good engineers for reasons of personality. There are, however, students who can meet the standards and would make good engineers; there must be reasons these students do not come to engineering schools. We must find these *reasons,* because in these reasons lie the answer to our input problem.

Could the reasons these students do not come be inertia, lack of funds, misinformation, poor publicity? To meet the financial difficulties that keep competent students from entering, more scholarships must be provided. Scholarships and funds now available should be used to their full extent. To overcome misapprehensions and lack of information, we must go to the high schools with our story. High school guidance people remember engineering employment as it was in 1950, and not as it is in 1955.

Generally each department or college of engineering has some ranking member assigned to placement of seniors. Would it be logical to assign some member to the procurement of freshmen? This may not be possible, but something should be done. Many private colleges have found that an active Director of Admissions who gets out and speaks in high schools, to various alumni groups, etc., can materially affect enrollment. Active alumni groups and interested individuals can all be effective boosters. Some means of copying these techniques should be instituted in schools that do not have them. Existing programs must be invigorated, and oriented to the need of society for engineers and to the opportunity engineers have in our society.

Increase the Efficiency

Perhaps one of the most effective means of bettering the ratio of the output of engineers to the input of freshmen would be to apply some quality control to the freshmen input. The purpose of such a program would be to exclude students who would not be likely to succeed at a college level, and to identify the weaknesses and deficiencies in preparation of students who have the ability to succeed. Such a system would be based on information secured on each entering student, such as high school record, data on the personality of the student, and the results of a series of tests given by the college.

If the goals of such a program could be met with precision, there would be many advantages. Much time, trouble, and money could be saved; advisers would be better prepared to counsel freshmen as to the fields for which they are best fitted. Such a procedure would also tend to forewarn the faculty and the student himself of any background weakness that might exist. Where weaknesses are known, creative measures can be taken. These efforts can be pinpointed to meet the specific needs of an individual *before* he fails a course.

When dealing with tests and measurements, we have the problem of the exception. The exception is a statistically insignificant fellow, but extremely important to himself. To compound this difficulty, some results of tests of this kind may not be clear-cut, since many persons have abilities that place them in a marginal group for our purposes. These difficulties are not beyond resolution since tests can be designed to meet carefully selected goals. We would not ask our tests to predict how well an individual would succeed in life (impossible), or how well he would succeed in college (difficult), or even whether an individual would succeed in college (reasonably easy). The test would be designed only to determine whether the individual had the equipment necessary to succeed in college (i.e., personality and mentality). If the student does not measure up to the standards of the college he should be rejected.

While the desirability of eliminating the poor material has been argued from the point of view of the college, an even better case can be made from the point

of view of the prospective student. It would be better to direct the energy of the student incapable of engineering toward a technical institute or trade school initially, rather than after he had failed in trying to master a higher education. For the individual, disappointment of relegation would be substituted for failure, obtainable goals substituted for goals unobtainable.

These carefully selected words are unnecessary when a private institution is concerned; colleges and universities supported by public funds are in a different category. Usually the prospective student entering a state institution needs only to earn a diploma from some high school in the state and it becomes practically impossible to refuse the student entrance on any grounds. Since the public colleges make up a large segment of our higher education system we must examine this admission policy that allows dissipation of resources and may tend to encourage situations that promote frustration. If the public institutions hold fast to an admission policy that allows the public to attend irrespective of ability, an economical classification system is obviated. The freshman year must be used as a classification test with the accompanying waste. This admission policy should be qualified, since no one should have the right to waste the substance of the state by working on a program for which he does not have the requisite ability. Such a policy then can become a means of saving resources by eliminating the obviously unfit, and a guide to the redistribution of these resources to those who need and can profit by the extra attention.

Every year prospective engineering students are dropped because they cannot seem to learn chemistry, physics, and mathematics. The bulk of these students have only casual contact with their chosen department. It is not argued that engineering students should take less or lighter work in these areas, nor is it argued that teachers in these areas are not doing their job. It is suggested, however, that students are getting more impersonal treatment in these departments, are getting herded into larger sections, and are getting less chance to work individually with their instructors than they receive in their degree departments. The difficulty has been approached with some success by sectioning courses on the basis of the ability and background of the students. The use of "honor sections" and "remedial sections" is a well known device that warrants wider usage.

Remedial sections, while helping to solve one problem, tend to create another, since they meet more often and receive the same credit as the other sections. This "stretching out" (extending the curriculum over longer periods than originally intended) can be dangerous unless it is accepted by the student. This problem is found often in another form: If a student fails a course, his first impulse is to take the course the next term. This is good, except that many students insist on keeping up with the class, which means they attempt to take all their regular work also. In this case the student has refused to recognize that he is being stretched out. It is particularly vicious since the students who are failing and taking the longer route through remedial sectioning are the marginal group. The overload caused by the extra work forced into the same period of time might well be fatal to them.

Systems for stretching out have been in operation for some time. One such system requires a student who has failed a course, depending on his cumulative average, to reduce progressively his course load including the repeated course. If the student's average indicates it is necessary, this system reduces his load to as little as three-quarters regular load and includes the repeated course and another course dealing with study habits, reading comprehension, etc. This system works two ways toward eliminating the student's problem. It stretches out the curriculum, and teaches the skills the student needs for academic success.

The Relation of Quality to Quantity

If we must have larger numbers of engineers and the needed students matriculate, does it necessarily mean that the quality of the graduate must deteriorate? Is there anything *a priori* in numbers that means reduced quality? A careful (although brief) analysis of the educational process will show that no deterioration need follow: in fact, some improvement of our graduates may occur because of an expansion, assuming adequate expansion takes place in our faculties and physical facilities. Three primary phases (as distinct from goals) of formal education will be examined—definition of content (curriculum), aiding the student to master the material (communication), and evaluation of his achievement.

The number of students matriculated should have no adverse effect on what may or may not be included in the curriculum. It might even be expected that some advantage might occur with greater numbers since larger selection of course offerings could justifiably be made with larger enrollments.

Another primary phase of the education process is communicating the ideas within the curriculum to the minds of the students. An individual having a thought he wishes to implant in the mind of another must deal with a complex system. The thought is communicated by being transformed into the written or spoken word; the word must be seen or heard, and arranged in the other person's mind in such a way that his behavior is changed. In the future, that person will react in a way that is conditioned by the thought transmitted to him; we have accomplished change in its most literal sense and every component of this change is liable to error. But is more error per student introduced because we have more sections of a given course? It would appear not, since the learning situation in one classroom is unaffected by what is happening in another room. Here again some advantage might be obtained, since larger enrollments can justify more equipment and teaching aids; more sections mean less difficulty in sectioning with better student schedules resulting. Student schedule improvement would not be a small gain, since we could not expect a student to learn much from eleven to twelve o'clock if he has been in class continuously since eight o'clock.

Objective evaluation techniques are necessary to judge accurately the accomplishments of the students. These techniques must also be developed so that quantitative experimental work can be done on our classroom communication problem. This lack of valid and reliable measuring instruments may limit some experimenting, but there are many fields in which much work can be done. Teaching aids, methods, reorganization of material can be tried in conventional or new forms. Every time a multiple-section course is taught, we have situations that lend themselves to controlled experimentation that should not remain unexploited. With larger enrollments we would have more multiple-section courses, and it seems clear that the additional sections would not increase the evaluation problem within the individual sections.

Summary

An engineering personnel shortage is a long-range problem that can not be solved immediately. However, we can start our solution immediately. These proposals offer steps that could be taken at once toward the solution of our output problem. The proposals deal primarily with the earlier portions of the college career where the mortality is highest; consequently they should represent a favorable beginning. The same type of organization should be extended through the entire curriculum and new techniques developed if we are to solve this problem. And solve it we must if the engineering education profession is to meet the needs of society and our national security.

Coordination of Architecture, Engineering, and Construction by the Project Method*

By JOHN F. POULTON
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The answers as to how to coordinate—in what manner and where and when—are intimately bound up with the collective personality of the school. They are modified by the school's attitude toward each of the phases of building and they are limited by the solutions which can be found within a given faculty and within the confines of the four year program. Certainly the answers which we have achieved at VPI fall short of our ideals. They are answers which are not easily reached and which evolve slowly. At the end of this paper I shall try to indicate the nature of what we have attempted so far at my school but I believe that specific answers are not nearly so important as is a careful consideration of the questions.

The first question which occurs to me in this connection is concerned with the precise definition of the professional fields for which we are educating. For the purpose of our discussion it is probably enough to limit ourselves to the Architectural Engineer although I think precision of definition in the other two areas is also needed. It is quite apparent that we vary a good bit among ourselves in our concept of the profession. I should like to advance a particular definition here both because my school believes in it and because it is involved in the viewpoint from which this paper is written. It seems to me that the architectural engineer is an engineer who is thoroughly familiar with and in sympathy with the objectives of architecture. He must have as profound an understanding as possible of each of the many current structural forms and he must be as competent as possible in their analysis and design. To this extent his objectives coincide with those of the Civil Engineer and his standards of competence should be at least as high. But beyond this point the Architectural Engineer must extend his insight to include understanding of the impact of these forms on architecture in both the visual sense and the economic sense. He should have an open, imaginative mind able to produce a number of alternative solutions to a given problem. He should be able to assess and weigh the factors involved, both tangible and intangible, in order to make a discriminating choice among the solutions. He is an engineer *for* architecture. His education is successful to the extent that he is profoundly aware of his status as an engineer.

Probably the most important of the questions which arise is concerned with what we mean by coordination and why we desire it. In the years since the war we have been increasingly concerned with the concept, sometimes calling it coordination but more often integration. It has commonly been held to describe a broadening of education to the end of reducing the graduate's tendency to specialize and increasing his competence in the fields related to his own. Most of us pay a certain amount of lip service to this idea. But we are very much aware of the increasing complexity of each of the areas

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of activity within the building industry and we are very much concerned to produce graduates who will be able to meet the detailed demands made upon them. We know the direction in which we should go—toward a broader and better rounded professional man—but the actual conditions of practice inexorably push us in the other direction. It seems to me that, in reality, we have had no choice in the matter. The very great increase in the complexity of the several fields is unarguable and we are concerned with conducting an education for people whose abilities have a quite finite limit. I am convinced that these forces will continue to bear upon us and that we will have no choice to continue the process of fractionating the building industry. There is nothing in the history of architectural education in this country since the first successful school was begun at MIT in 1868 to suggest that the trend will be reversed.

It is frequently argued, notably by Felix Candela, that significant building can be accomplished only by a return to the idea of the Master Builder of the Middle Ages. This envisions a person who has encompassed all the knowledge we expect in each of the fields into which we have broken building. It is an exciting and stimulating thought but it seems to me that this kind of stature is possible only to the genius. If we are to take as our responsibility the education of *enough* people to fill the needs of our building industry then certainly the number of men of genius to be found among our students will be only a very small per cent of the whole. If Candela's thought is correct—and I think it is—we must seek a way to approximate the Master Builder. If we cannot achieve him in one person then we must try to approximate him in several.

Within this idea I believe we have the start to a better understanding of the notion of coordination or integration or whatever we wish to call it. Briefly, it seems to me the situation is this: building has become very complex—so complex that people of normal ability are unable to encompass all the necessary skills and knowledge involved in it. Indeed, they are hard put to attain real competence in even one of the fields into which we have divided it. Then, if these people are to contribute to significant building, ways must be found for them to bring their several abilities to bear on one project in the sense that a Master Builder would bring many abilities to bear on it. What is needed is a very considerable skill in collaboration and a recognition of that skill as an important element in the total competence of each of our people—the Architect, the Architectural Engineer, and the Contractor. The coordination required is not that which will give each individual some broadening of his technical competence into the fields adjacent to his own, but, rather, should increase his skill in the process of collaborating with those who are in the adjacent fields.

Of Primary Importance

In the past we have, to some extent, recognized the need for skill in the collaborative effort but I think we have not placed nearly enough emphasis upon it. We have acted as if it were a quality quite secondary to the student's technical competence and we have assumed that it could safely be left to be developed in the early years of his professional career. It seems to me that it is, in fact, of primary importance and that the schools must recognize education for the development of the skill as an added responsibility.

Moreover, this is one addition to our education which can be accomplished within the framework of a four year course for it involves no new subject matter. The ability to collaborate with others is made up principally of insight into the problems and objectives of the other fields and of a mature and healthy respect for the work of others. Education for the development of the skill can be accomplished through care in

establishing the sequence of work, through teaching which is consistently concerned with the relation of one field to the others, and, perhaps most important of all, through conducting education in an atmosphere of concern for the interests of all three fields.

The schools which offer curricula in Architecture, Architectural Engineering, and Building Construction are fortunate since the presence of all three curricula in a single department is helpful in establishing this atmosphere. When this is done much of the desirable effect comes about informally. The students observe each other's work and extend their awareness of problems beyond their own fields in casual conversations. Also, they are able to see a core of interests which is common to all three activities. The fact that such subjects as elementary design, elementary structures, and estimating are studied in joint classes tends to increase the students' understanding of the interrelationships which exist among their several interests.

It must not be inferred from what I am saying here that I believe it is proper or even possible to extract from each curriculum all of the technical material relating to either of the other two. On the contrary, I believe that an understanding of the basic concepts in all three fields is quite necessary to effective collaboration. The architect must be familiar with the fundamentals of mechanics before he can work cooperatively with the engineer. Moreover, there will continue to be circumstances in which it is desirable for the architect to be able to carry out simple structural design without resort to collaboration. There are also times when the engineer must undertake simpler architectural functions and he should be able to carry them out adequately. But it does not seem possible to extend the student's factual education in adjacent fields beyond the level of the fundamentals. It seems to me that education which attempts to do so is disregarding the nature of the present day practice for which the students are preparing, it is likely to give the student a poor understanding of the nature of his profession, and it is certain to leave too little time for the study of his own professional field.

The coordination we should seek is not that which invites the student's attention to every phase of building with each problem. Rather, it will consist in a more vigorous study of a single phase but with the relation of that phase to the remainder of building activity constantly borne in mind.

The final question which might occur to us is concerned with the meaning of the term The Project Method. In "Engineers and Ivory Towers," Hardy Cross says of engineering:

> "Engineering is essentially a craft. It is the glory of engineers that they are craftsmen, that they are artists, and while as good craftsmen they follow a systematic and orderly procedure, they are highly resistant and antagonistic toward overregimentation. They demand freedom for their art, freedom to recreate, to rearrange."

This is the concept of engineering which seems to me soundest and particularly so where Architectural Engineering is concerned. If we accept the concept and undertake to emphasize the idea of engineering as an art making use of science, then, in education, we must try to provide circumstances in which the student may explore the art and practice in it. It seems to me this is the idea we have in mind when we speak of the project method. We are concerned with the thought that the principal and most difficult phase of engineering is that of attaining insight into the problem presented by the whole building and that it is upon this problem that the student's attention must be focused. He must attack his problem in such a way as to achieve a unified and meaningful result. Only after he has determined the need of the whole building will he turn his attention to the individual structural elements which compose it. When he has done this he will

have his understanding of the unity of his work to bring intelligent discipline and order to his detailed computations.

The relative difficulty of the two phases of structural work has shifted. Not many years ago the problems involved in framing buildings lay largely in the field of mechanics. We were concerned with quality of materials, with analysis of linear frames in fairly simple senses, with means of jointing, and with foundation problems. We were able to feel that if we had become competent in these matters we had our subject fairly well in hand and that the application of our knowledge to an actual building was a simple matter. The means and patterns of framing available were few and stereotyped and were usually dictated by an architectural solution which had been reached with very little consideration of structure.

Multiplied Many Times

But recent years have seen multiplied many times the means of building available to us. The advent of such elements as structural glueing and welding, precasting and prestressing, folded planes and shells, diagrid framing and lamella forms—to name only a few—have made the matter of choosing structural materials and structural forms anything but simple. At the same time structural elements have become more and more important in the visual character of buildings. We are finding, especially in school buildings, the entire nature of buildings dictated by economic factors related to their framing. The choice of a structural solution has become a decision affected by many factors of which some are tangible and calculable but more are intangible and non-numerical.

As a consequence, then, the most difficult phase of the work of the Architectural Engineer lies in the selection of materials, forms, and arrangements appropriate to a given architectural circumstance and in the organization of his work to take the many factors into account.

Structural analysis and the design of individual structural elements are subjects as difficult for students as they have always been but they have become only tools in the solution of larger problems.

Under these circumstances, it seems to me that the most effective engineering education will be that which makes maximum use of the project method and minimizes lecture courses. The ASEE Committee on Evaluation of Engineering Education seems to have indicated the same sort of thinking in its recommendation of augmented courses in design.

The idea of minimizing lecture courses does not, of course, carry with it any thought of minimizing the attention given to theory of structures. The change is from a situation in which the theory is taught as an end in itself to one in which it is presented as an integral part of a given problem. The amount of teaching done is unchanged, it has simply been transferred to and made part of the courses in structural design. The work is given piecemeal as needed in successive problems. There are dangers in this method, of course. The student is likely to miss the generality of application of a given point. But this has always been true of structural theory under either method and the teacher has always had to be careful to make clear the extent of the area over which a given element of theory is applicable.

The chart which follows shows the way in which the Architectural Engineering curriculum at VPI is organized at present and the degree to which we have been able to put these ideas into effect.

Supporting Subjects		Courses in Design
		All Curricula
Fall 1st Yr. Fnd. Dwg. Intro. to Arch. Algebra	1	Elements of drafting
	2	Orthographic projection
	3	
	4	
	5	Isometric drawings
	6	Elements of descriptive geometry
	7	
	8	Shades and shadows
	9	
	10	
Wint. 1st Yr. Fnd. Dwg. Intro. to Arch. Trig.	1	Construction of perspective
	2	Perspective drawing
	3	Perspective drawing
	4	Perspective drawing
	5	Two-dimensional design—composition in lines
	6	
	7	Two-dimensional design—composition in shapes
	8	
	9	Two-dimensional design—composition in shapes and textures
	10	
Spr. 1st Yr. Intro. to Arch. Anal. Geom.	1	Three-dimensional design—folded paper in plane form
	2	Three-dimensional design—folded paper in form with depth
	3	Three-dimensional design—pressed paper in spatial and structural study
	4	Three-dimensional design—any material in spatial and structural study
	5	
	6	Three-dimensional design—study of inter-related transparent and opaque planes
	7	
	8	Three-dimensional design—study of space composition in planes involving open and closed forms
	9	
Fall 2nd Yr. Calculus Physics	1	Simple planning and function—a kitchen—interior only
	2	
	3	Simple planning and function—a guest cottage—interior and exterior
	4	
	5	
	6	Resolution and composition of forces
	7	Resolution and composition of forces
	8	Analysis of a truss
	9	Analysis of a truss
	10	Analysis of a truss

Supporting Subjects		Courses in Design		
		Architecture	Architectural Engineering	Building Construction
Wint. 2nd Yr. Arch. Hist. Calculus Physics Statics	1 2 3 4 5 6 7 8 9 10		None	
Spr. 2nd Yr. Arch. Hist. Mech. of Mat'ls Calculus Physics	1 2 3 4 5 6 7 8 9 10		Design using rustic materials—resort building Working drawings for resort building Analysis of forces in three dimensions Analysis of forces in three dimensions Topography and earth quantities Topography and earth quantities	
Fall 3rd Yr. Diff. Eq. Mat'ls & Meths. Structures Surveying	1 2 3 4 5 6 7 8 9 10		Specifications Estimating Structural design—roof framing only for small, wall bearing assembly building—wood	
Wint. 3rd Yr. Concrete Elec. & San. Equip. Mat'ls & Meths.	1 2 3 4 5 6 7 8 9 10		Structural design—framing for small building requiring only simple span construction—steel Design—small building of utilitarian character—suitable for development in later engineering problems	

Supporting Subjects		Courses in Design		
		Architecture	Architectural Engineering	Building Construction
Spr. 3rd Yr. Heating Mat'ls of Engr.	1		Structural design—framing for above building—concrete—introduction to indeterminate analysis	
	2			
	3			
	4		Working drawings—for above building including structural features	
	5			
	6			
	7		Electrical design—for above building	
	8			
	9		Plumbing design—for above building	
	10			
Fall 4th Yr. Elems. of Indet. Strs. Structures	1		Structural design—a mill building, superstructure only—principal frames developed in both three-hinged and two-hinged forms	
	2			
	3			
	4			
	5		Heating and ventilating design—for building from Winter of 3rd year	
	6			
	7			
	8			
	9			
	10			
Wint. 4th Yr. Prof. Prac.	1		Structural design—a multi-story building of simple plan—detailed consideration of problems of indeterminacy with especial reference to horizontal loading—concrete	
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
Spr. 4th Yr. Structures	1	Design—a public building of considerable complexity—most recent, a convention building	Structural design—a retaining wall, designed as both cantilever and counterfort	
	2			
	3			
	4		Structural design—collaborative study with architectural students—students paired in architect-consultant relationship	
	5			
	6			
	7		Financial study—economic factors affecting building decision	
	8			
	9			
	10			

You will see that the first four quarters are identical for all three curricula in so far as the major elements of the work are concerned. The greater part of this is the material usually offered to students in Architecture but the faculty members who conduct it have been very effective in assuring that its application to all three curricula is made clear. Its principal value for the Architectural Engineering students probably lies in an increased understanding of architecture and architectural thought. But we have found that the work in the Spring quarter of the first year has made a very considerable contribution to their insight into the nature and behavior of structures and, also, to their ability to visualize three-dimensional constructions. This work is the especial hobby of one of our teachers. The entire quarter is devoted to building three-dimensional constructions of common materials including paper, thread, toothpicks, and sheet plastic. In all the exercises, the ability to carry load is emphasized along with the aesthetic properties—the two are coordinated—and the students are required to study the appropriate shapings of these materials to achieve maximum strength.

Starting with the Spring of the second year, the Architectural Engineering students begin the series of problems designed to develop their especial interests. The nature and development of this work is readily understood from the chart. We have tried to conduct as much of it as possible in relation to realistic building problems in order to draw the students' attention to the associated problems in architectural design and in construction practice. We have not been entirely successful in maintaining this relationship but you will see that the first half of the Spring quarter in the second year covers a fairly well rounded problem. All of the work in the Winter and Spring quarters of the third year and a part of that in the Fall of the Fourth year are concerned with a single building. We hope that by such means we are leading the students to a broader view of their profession and its relation to others.

In the Spring of the fourth year we have introduced four weeks of work in which the students in Architecture and those in Architectural Engineering actually collaborate on a single project. We would like to introduce more of this but we find that students at lower levels have not enough competence in their own fields to be able to make contributions to each other's thinking. Also, it is very difficult to introduce new engineering concepts to the students while they are preoccupied with the difficulties of this work and we find that, although it is valuable training in the architect-consultant relationship, it is not very efficient instruction in purely engineering matters. Hence, the time available will not permit extension of this sort of teaching.

Annual College-Industry Conference Relations with Industry Division

January 26, 1956 Marquette University

The theme of the conference will be "Humanities and Engineering." The panel discussions will include the place of humanities in research, design or development, sales engineering, and manufacturing operations.

A Method of Teaching Leadership to Engineering Students

By REYNOLD K. WATKINS

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Engineering educators point proudly to the high percentage of their former students who are called to executive positions in industry. Apparently, something about the technical training of an engineer prepares him for leadership. Perhaps it is the engineering approach to the solution of problems. From the beginning of his training, the engineer is taught to collect all available data, to draw a diagram, and to reason through to a logical conclusion. Fortunately this fundamental process is susceptible of general application to problems of policy level as well as to problems of a technical nature. Other types of education may emphasize examples and cases by the volumes, big formulas to grind, or facts and statistics; but these tools, like an awl in the hand of a cobbler, are generally limited in function. They can seldom solve a problem in policy or generic planning.

Many engineering executives declare that they have gained positions of responsibility in spite of rather than because of any direct attempt by their teachers to prepare them for leadership. Indeed, some executives feel that engineering education stunts growth in leadership because of heavy assignments which take all of the student's time, and because of the emphasis which teachers place on technical achievement. Whether or not this statement should be accepted without qualification, the general point suggests that something should be done to better prepare engineering students for eventual leadership.

To most of us, leadership means the authority given one person to direct the activities of others. Accordingly, a prospective leader may suddenly find himself in the role of a project director with an assignment to be the boss and get the job done. The primary difficulty is that the newly created boss does not know how to direct men, and can use only a few techniques that he has seen his own boss use before him. His position is worsened by the psychological makeup of the modern-day, free-thinking laborer. If the young leader fails to get the job done, he is relegated to the ranks of the subprofessionals or to a position in research or detailing; he is left here until another opportunity may arise for him to prove himself a leader. Under this authoritarian type of leadership, he can rise to a position of leadership only by appointment, but he can gain no appointment unless he can lead. Surely something is wrong. Maybe leadership needs a different definition.

Theory of Leadership in Small Groups

In recent years, many of America's outstanding sociologists have turned their attention to the social dynamics of small groups of individuals, a science popularly known as Group Dynamics. Some new concepts of leadership have come from this science. One of the more productive concepts has been proposed by Cattell, who reasons that leadership in its most effective form is a product of the group. This means that the group leadership is not necessarily vested in one person, a chairman, and that all the others are followers. Any group of individuals within

a very few minutes develops a kind of group personality called syntality. If the syntality of the group remains constant, there is no evidence of leadership. However, if the syntality changes as the group works or plays together, then leadership is manifested. Leadership might be defined, therefore, as the change in syntality of the group. A leader is anyone who in any way contributes to that change in syntality. He need not necessarily be the chairman. More likely than not, a formal organization having a chairman tends to suppress rather than encourage the spontaneous changes in syntality that group members are able to contribute. An example follows.

Usually the officers in student engineering organizations receive explicit instructions from their faculty adviser about conducting the activities of their organization. This year when the adviser met with the student officers the first time, he sat informally with them and after making one or two suggestions to provide some direction, he turned the problem over to the students. It took a few minutes plus a few jokes to put them at ease, but soon they commenced to make suggestions for their own chapter program. Each idea suggested others, and before the meeting was over the student program had been completely "brainstormed." The ideas finally adopted were much better than usual. Field trips and special events were planned that never had been thought of before. The excellence of the plan plus the enthusiasm of the student officers gave the adviser assurance that the program would be carried out successfully.

It does not follow that leadership always results in good. For example, the total change in syntality may tend toward discouragement; then the group may not even attempt to solve its problems or to play its game. Such a state of frustration might arise as to result in dissolution of the group. Frustration often results from non-participation of one or more members, or from disagreement among the members. In student engineering groups, though, the disagreement is a minor concern; for if sufficient time is allowed for solving the problem, the correct point of view usually can be demonstrated. The greatest danger to the group then remains the danger of non-participation. The non-participant may simply be shy, or he may be antagonistic; however, any normal participant not knowing the attitude of the non-participant is likely to assume the worst and then feels inhibited in his own participation. From the foregoing discussion:

1. Leadership is defined as change in syntality of the group or team.

2. Leadership in its most effective form must arise spontaneously from all members of the team; non-participants inhibit leadership.

Effectiveness of the Team as a Dynamic Group

Since the purely authoritarian type of leadership illustrated in the beginning seems to be losing its effectiveness with the modern American laborer, one might inquire under what conditions the worker does respond to leadership. If these conditions are found, then possibly a method can be developed for isolating and measuring leadership. One set of conditions under which the worker usually responds is teamwork, a spirit of which is strongly planted in the hearts of American youth through a wide variety of team contests. It is easily recognized that the team concept satisfies the two statements of leadership above. Surely the development of team spirit manifests an increase in syntality of the group. Surely the leadership is supplied in varying amounts by all members of the team; and of course the team fails if one or more members refuse to participate. It appears quite natural that American love for the team could provide an energizer for development of leadership within a small group. The necessary elements are the team, a problem to be solved or a lesson to be learned, and a reason for doing it.

The team spirit idea was tried by the author in a Contracts and Specifications

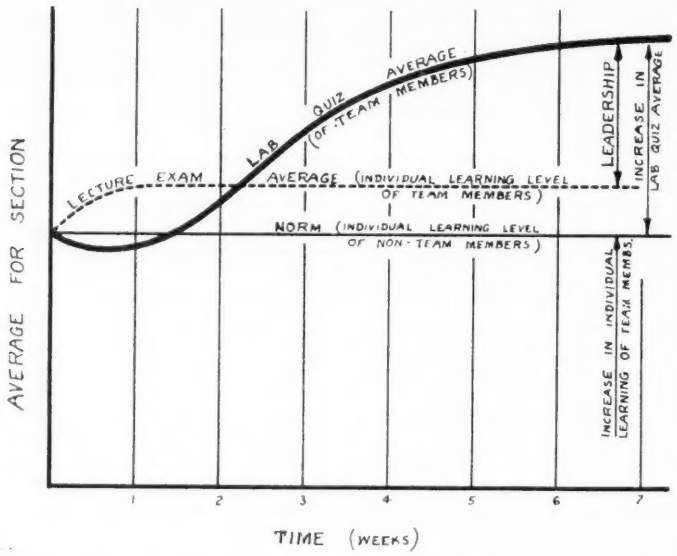
course. Several periods were first devoted to learning some facts about law and contracts; then the class was divided into five-man teams. Members of each team became the sole and equal stockholders in an engineering company. Of course the stockholders had to meet and organize their own engineering firm. A list of their assets was given to them. Each firm was made responsible for writing its own articles of incorporation. All firms were then assigned a construction project, and were asked to draw up necessary contract documents for letting out the project for bids. In this capacity each engineering firm was agent for an imaginary owner. The next assignment inverted the situation; each firm became the bidder on a project for which contract documents had been written. In both assignments the firms were competing against each other. The bidding was extremely lively, for bids were received and opened according to usual procedures. The actual minimum cost of the hypothetical project had been calculated previously by the instructor, and bids were thrown out as a penalty for bidding dangerously below cost. The lowest bidder above minimum cost won the most credit on the bid submitted, provided the form was acceptable. Next lowest bidder was second in credit, etc. Enthusiasm of the class was much better than it had ever been before in Contracts and Specifications. Although measurement of the quality of the work in comparison to that done in other years was difficult, the results seemed generally superior. Certainly grades on examinations were better. The group dynamics approach had proved a superior educational technique.

Team Dynamics Develops Leadership

The above example demonstrates the effectiveness of group dynamics through problem-solving teams and proves the power of the team to raise the learning level in certain college courses; but it does not indicate that the raise is due to leadership in the teams.

An attempt to isolate leadership was made in three problem-solving laboratory sections in Engineering Mechanics. Each section met weekly for a 3-hour period. The object of the course was to teach students how to apply principles of engineering mechanics to the solution of problems; but it was felt that an opportunity might also exist to suggest a few pointers in leadership and to give the students opportunity to develop leadership in small groups.

Section A was assigned problems that each student had to solve independently. Students were allowed to consult individually with the instructor, but were prohibited from consulting with anyone else. During the last 30 minutes of each 3-hour period, a quiz was given on the problems they had been studying. Section B was assigned similar problems, but students were divided into 3-man teams. Each week the teams were changed so that every man had opportunity to work with every other man in his section. The last 30 minutes of the period was devoted to a quiz on the problems. Section C also was assigned problems, with a quiz at the end of the period, but the men were allowed to work in teams of their own choosing. Once the team was set up, it became permanent for the duration of the course. Section A was considered norm. At the end of the course the quiz average for Section B was 12% higher, and the average for Section C was 39% higher than the norm. These results were weighted to eliminate variations in group capabilities. Variations were determined by a 4-week period at the beginning of the course when all students worked independently as described for Section A. It is noteworthy that the temporary groups in Section B did not develop into the successful problem-solving teams that the permanent groups in Section C developed into. The results of these lab quiz averages for each section were plotted on a graph of lab quiz average versus time in weeks. In this experiment the results were rough and erratic, but the general trend for Section C is



shown on the figure. Again the results show that use of group dynamics raises the learning level, but in this experiment it was assumed that part of the increase in lab quiz average resulted from leadership within the team—not just an increase in individual learning. One would expect that increase in individual learning would occur as the students check each other's answers, compare methods of solution, and instruct each other. A plot of individual learning in the group versus time would be expected to rise suddenly and remain constant as shown by dotted line on the diagram. This curve was evaluated by giving a series of exams during lecture to the combined sections. Those students who had been members of teams clearly had a higher lecture exam average, as shown by dotted line, but the increase was very small in comparison to that of the lab quiz average. The major part of the increase in lab quiz average, then, must reflect a substantial increase in the ability of the team (not the individual) to solve problems. This increase is precisely a change in syntality of the group and therefore can represent nothing else than leadership. Put into a formula, leadership is measured by the increase in lab quiz average minus the increase in individual learning. Typical values are indicated on the diagram. It is interesting to note that the group leadership develops slowly at first; in fact, it is virtually negative the first week when the members are learning how to react to each other in the team situation.

Part the Instructor Plays

The instructor can hardly determine which students are benefiting most from this development of leadership. Surely he could not give each man a grade in leadership on the basis of these results. Nevertheless, the very fact that somebody is developing leadership is valuable to engineering education.

The time may come when sociologists can prescribe more powerful methods for applying Group Dynamics. When such a time comes, the engineering teacher may be able to outline principles and techniques so that all students may launch immediately into successful group problem-solving situations. Even without a

perfect understanding of Group Dynamics, there are a few things a teacher can do to prepare students for group experiences. He should warn against authoritarian organization of the group because such organization stifles spontaneous leadership of the members. He must insist that all members of the group participate. Finally he can supply incentive and direction for the teams as they seek their problem-solving goals. Incentive may or may not be in the form of competition.

If engineering educators would adopt group dynamic or team methods under appropriate circumstances they would not only realize an increased level of individual student learning, but they would greatly stimulate leadership development. The extent to which spontaneous leadership within a team can prepare an engineer for formal leadership of industrial firms can be determined only after a fair trial; but even with partial success, the future leaders of American industry would be deeply grateful.

Publications Available

EDUCATIONAL AIDS FOR ENGINEERING

Prepared by the Teaching Aids Committee of the ASEE, a catalog listing more than 5000 teaching aids in the fields of mathematics, mechanics, civil, mechanical, and electrical engineering is again available. It describes 290 devices which were rated by the ASEE reviewing committees as the best available for engineering education; examples include a television demonstrator to supplement the teaching of communications, circuits, and electronics, a hydraulic demonstrator which illustrates various phases of fluid mechanics, 16 mm. motion pictures and 35 mm. film strips, plus other simple and ingenious ways to dramatize learning. The catalog explains the principle and nature of each aid, equipment necessary, where the equipment can be obtained, and costs. The spiral-bound volume, at $1.00 per copy, is 8½" by 11" and has 72 illustrated and indexed pages. Orders should be sent to the ASEE Office, University of Illinois, Urbana, Illinois. Send for one today!

ILLUSTRATIVE PROBLEMS IN ENGINEERING

A source of typical engineering problems and examples in Dynamics, Elasticity, Electricity and Magnetism, Electronics, Fluid Flow, Heat Transfer, Materials, Statistics, Systems, and Creative Ideas is now available in General Electric's new inch-thick volume, *Illustrative Problems in Engineering*. Compiled by the Company's Engineering Training and Education Section, the problems are those which students are likely to encounter in industry, but which are frequently omitted from textbooks and are not readily available to engineering instructors. This hard-backed volume is separately paged by topics and is available to members of college faculties. Write to: Engineering Recruiting Section, General Electric Company, One River Road, Schenectady, New York.

GRAPHICAL SYMBOLS FOR PLUMBING

A new American Standard Graphical Symbols for Plumbing has been developed by the ASA Sectional Committee on Standardization of Graphical Symbols and Abbreviations for use on Drawings, and approved by the American Standards Association. Copies may be obtained from The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York.

Report of the Engineering School Libraries Committee, 1954–55

By J. H. MORIARITY

Director of Libraries, Purdue University

The Committee carried on considerable inter-member contact and made one general mailing to librarian members in the Northeast states. There were regional meetings of the librarian members, but reports of only two such meetings reached the Chairman. More close check of such activity will be made in 1955–56.

The Annual Meeting offered an opportunity to hold two meetings. A luncheon business meeting was useful as such, but actually turned into an advisory panel of the librarians in order to help two instructors who joined the luncheon. These instructors presented local institutional problems of a library nature which were worrying them in connection with their teaching. Considerable advice of a worthwhile nature was given to them.

The two papers presented at the open meeting, June 23, were:

1. Information Searching Habits of Engineers and Scientists. Saul Herner, Atlantic Research Corp.
2. Scholarly and Professional Library Experiences. Thomas J. Higgins, University of Wisconsin.

The presentation was excellent and the discussion among the twenty librarians at the meeting continued until past 4 P.M.

Teaching Salaries Then and Now

Under the auspices of the Fund for the Advancement of Education established by the Ford Foundation, Beardsley Ruml and Sidney G. Tickton have recently completed an economic investigation of teaching salaries over the past fifty years. Their comprehensive study is summarized in the new 93-page, 6″ by 9″ bulletin Number 1, *Teaching Salaries Then and Now.* Rather than telling what teaching salaries should be, the bulletin clearly reveals how these salaries stand today in relation to incomes in other fields. This discussion-provoking report can be obtained from the Fund for the Advancement of Education, 655 Madison Avenue, New York 21, New York. The report will be of considerable value to teachers and administrators alike.

The Engineering Economist

The Engineering Economy Committee of the ASEE announces its quarterly publication, *The Engineering Economist,* devoted to engineering economy and related fields. The publication implements the work of the Economy Committee by publishing original articles, papers presented at the annual meeting of the Committee, reprints of articles appearing in other publications, book and speech reviews, reports on problems involving economics in engineering, critical comments, and exchanges of ideas. To ASEE members subscriptions are $1.50 per year for four issues, and to nonmembers $2.00 per year. Single copies are 75 cents. Subscriptions may be addressed to: Box L, *The Engineering Economist,* Stevens Institute of Technology, Hoboken, New Jersey.

Report of the Auditor

September 27, 1955

Executive Board
American Society for Engineering Education
Urbana, Illinois

Gentlemen:

In accordance with your instructions we have made an audit of your records for the year ended June 30, 1955, and herewith submit our report, consisting of a balance sheet and the related statements of income and expense and of changes in account balances. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Following past practice, inventories of Society publications are not included in the balance sheet. The costs of publication have been charged to operations in the year of printing.

In our opinion, the accompanying balance sheet and statements of income and expense and of changes in account balances present fairly the financial position of the American Society for Engineering Education at June 30, 1955, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Respectfully submitted,

(Signed) FILBEY, FILBEY & BEAGLE,
Certified Public Accountants

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Balance Sheet

June 30, 1955

CURRENT FUND

ASSETS

Cash:		
Checking accounts	$15,888.54	
Savings accounts	25,405.12	$41,293.66
Petty cash		300.00
United States Government obligations at cost, plus accrued interest of $93.75		46,793.75
Accounts receivable:		
Advertising	$ 2,920.01	
Dues	1,800.00	
Westinghouse Education Foundation	257.23	
Due from B. J. Lamme Fund	305.07	5,282.31
Unused advances to Humanistic-Social Research		2,550.78
Deposit for air travel card		425.00
Office supplies		210.00
Inventory		1.00
Furniture and equipment		1.00
Total Assets (NOTE)		$96,857.50

LIABILITIES AND SURPLUS

Accounts payable and accrued expenses		$14,133.68
Dues collected in advance		656.65
Excess of contributions over expenditures (NOTE):		
Educational Aids	$ 2,392.07	
Evaluation of Engineering Education	8,393.12	
Humanistic-Social Research	8,214.03	18,999.22
Surplus:		
Reserve for special projects	$ 5,317.19	
Reserve for ECRC	5,093.93	
Unappropriated surplus	52,656.83	63,067.95
Total Liabilities and Surplus (NOTE)		$96,857.50

B. J. LAMME FUND

ASSETS

Cash	$ 290.25
Income cash in hands of trustee	290.70
Principal cash in hands of trustee	5.51
Securities and mortgages	10,136.22
Total Assets	$10,722.68

LIABILITIES AND SURPLUS

Due to current fund	$ 305.07
Surplus	10,417.61
Total Liabilities and Surplus	$10,722.68

NOTE: As of June 30, 1955, $18,999.22 of the total assets of $96,857.50 represent amounts received from outside organizations to be used for special projects. These amounts are not available for general Society operations.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Statement of Changes in Account Balances

For the Year Ended June 30, 1955

CURRENT FUND

Educational Aids

Balance, July 1, 1954		$ 6,767.51
Deduct:		
Expenditures	$ 3,250.44	
Income from teaching ads for the year ended June 30, 1954 transferred to unappropriated surplus	1,125.00	4,375.44
Balance, June 30, 1955		$ 2,392.07

Evaluation of Engineering Education

Balance, July 1, 1954	$ 5,012.45
Add:	
Contributions	13,000.00
Total	$18,012.45
Deduct:	
Expenditures	9,619.33
Balance, June 30, 1955	$ 8,393.12

Humanistic-Social Research

Balance, July 1, 1954	$20,457.15
Deduct:	
Expenditures	12,243.12
Balance, June 30, 1955	$ 8,214.03

Reserve for ECRC

Balance, July 1, 1954	$ 6,430.19
Add:	
Sale of ECRC publications	336.28
Total	$ 6,766.47
Deduct:	
Excess of ECRC expense over the budgeted amount	1,672.54
Balance, June 30, 1955	$ 5,093.93

Unappropriated Surplus

Balance, July 1, 1954		$46,829.86
Add:		
Net income for the year ended June 30, 1955	$ 4,701.97	
Income from teaching ads for the year ended June 30, 1954 transferred from educational aids	1,125.00	5,826.97
Balance, June 30, 1955		$52,656.83

B. J. LAMME FUND

Surplus

Balance, July 1, 1954	$10,316.06
Add:	
Income	327.14
Total	$10,643.20
Deduct:	
Expense	225.59
Balance, June 30, 1955	$10,417.61

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Statement of Income and Expense

For the Year Ended June 30, 1955

		Actual	Budget	Difference Favorable (Unfavorable)
Income				
Individual dues		$49,652.40	$49,100.00	$ 552.40
Institutional dues		12,537.00	12,000.00	537.00
Sale of publications		4,010.23	2,800.00	1,210.23
Advertising		20,629.20	20,000.00	629.20
Teaching ads		735.88	—	735.88
Interest income		1,404.62	780.00	624.62
ECRC	$ 336.28			
Less amount credited to the reserve for ECRC	336.28	—	—	—
Refund from annual meeting		357.28	—	357.28
Miscellaneous		1.24	—	1.24
Total Income		$89,327.85	$84,680.00	$ 4,647.85
Expense				
Annual meeting		$ 2,351.32	$ 3,000.00	$ 648.68
Journal and *Proceedings*		32,343.35	30,000.00	(2,343.35)
Committees and conferences		612.69	2,000.00	1,387.31
Postage and telephone and telegraph		2,942.20	2,500.00	(442.20)
Supplies, expense and sundry printing		5,319.89	4,500.00	(819.89)
Travel expense—secretary's office		1,994.19	2,000.00	5.81
Officers' travel expense		3,061.21	3,000.00	(61.21)
ECAC		498.14	2,200.00	1,701.86
ECRC	$ 6,022.54			
Less amount charged to the reserve for ECRC	1,672.54	4,350.00	4,350.00	—
Administrative salaries:				
Secretary	$ 7,962.50			
Assistant secretary	3,240.00			
Office secretaries	12,207.89			
Clerical assistance	299.43	23,709.82	23,500.00	(209.82)
Retirement of emeritus assistant secretary		1,360.00	1,360.00	—
Bonding fees and auditors		924.70	375.00	(549.70)
Dues (American Council on Education)		200.00	200.00	—
ECPD (contribution)		500.00	500.00	—
Contingencies and special projects		927.34	2,000.00	1,072.66
EJC dues		573.00	700.00	127.00
Moving		1,384.85	—	(1,384.85)
Utilities		233.55	—	(233.55)
Furniture		1,314.71	—	(1,314.71)
Refunds		24.92	—	(24.92)
Total Expense		$84,625.88	$82,185.00	($ 2,440.88)
Net Income		$ 4,701.97	$ 2,495.00	$ 2,206.97

NOTE: The statement of income and expense reflects the general Society operations. Contributions received and expenditures made in connection with the special projects listed in the balance sheet are not shown in this statement.

Candid Comments

Grading of Exams

By RALPH H. UPSON

Professor of Aeronautical Engineering, University of Minnesota

Professor Sanks' interesting paper on this subject in the March JOURNAL brought out some worthwhile aims, to which no one should object. Examinations should certainly be interesting and instructive, as well as revealing. His eloquent plea for raising the standards of individual responsibility should be heeded by all. Yet, his first conclusion is of questionable validity as implying the necessary means to these ends. His advocacy of no credit for inaccuracies, as interpreted by the context, apparently means to grade entirely on the basis of an accurate numerical answer, with zero credit for the entire problem otherwise. Granted, that individual responsibility on the part of the student is one of the most important characteristics to develop; still it should seem obvious, even to a student, that there are other factors than numerical accuracy involved; and one of the best means of developing responsibility in the student is the example of a teacher willing to go to the necessary trouble to evaluate the various interrelated factors of which a good examination paper is composed.

Recently this same article came up for discussion in a small group composed of four professors and four scientists, two of the latter from industry. The opinion was unanimous that accuracy is not all-important, especially on the undergraduate level. An engineering representative from one of the leading aircraft manufacturers brought out that anyone can make a mistake, regardless of how well trained and how high his sense of responsibility. Therefore, all important quantitative results and equations *must* be independently checked, as witness no less an authority than the late Dr. Einstein. Numerical checking is fairly simple with modern computing machines. Furthermore, most engineering data, criteria and formulas are inherently inexact, and there is no point in carrying the end results to a disproportionate accuracy. For many purposes of preliminary design, an accuracy within 15% is all that can be expected or desired. Here, sound thinking and resourcefulness are far more important than accuracy. From the professors' group, the only advantage mentioned for the proposed system of grading was that it is certainly easier for the teacher. In this and other respects, it would seem to be in a similar category with the equally reactionary but still controversial closed-book examination. The combination of both these features is of course nothing new, but represents the most primitive type of examination, the kind which now can be graded by machine. Or, as one conservative remarked, "That's not engineering; that's bookkeeping."

Coming back to present students' papers, a proposed method of improving the fairness of the credit-for-accuracy-only type of test is subdividing a problem into a number of parts. It is apparent that with sufficient subdivision and with no more than one penalty for the same mistake, the two systems would be really the same in effect except for the varying seriousness of possible mistakes.

It is easy to say we want accuracy, and nothing else will count; but there are many kinds and gradations of errors, ranging from the trivial to the fantastic. To name but a few:

1. Slide rule inaccuracy.
2. Omission of an unimportant factor such as $(1 - \mu^2)$.
3. Omission of an important factor such as 2 or $\frac{1}{2}$.
4. Misplacing the decimal point.
5. Failure to convert inches to feet or vice versa.
6. Units or direction omitted.
7. Use of engineering resourcefulness to reach an approximate answer.
8. Realization that the answer is incorrect.
9. Answer correct but procedure not clear.
10. Misunderstanding of question.
11. Correct procedure but ran out of time.
12. Correct use of erroneous answer to one problem to solve another.
13. Lack of judgment in using erroneous data from book or notes.
14. Application of a semi-empirical method to a questionable range of conditions.
15. "Formula snatching"; total misapplication of a formula.

Does Mr. Sanks mean to imply that any or all of the above errors should be treated with equal ruthlessness, denying all credit for the problem involved? Based on his experimental course procedures, about the most credit that he would ever consider for sound theory is one-half, and he opposes even that. Personally I mark on the basis of *deduction* for errors, with never more than 10% penalty for an individual arithmetical error unless the student should have been able to see by inspection the absurdity of his result. In the case of item 7, I impose no penalty whatever if the resourcefulness is judged to balance the error, because under no circumstance should the student be discouraged from original thought.

If it can be conceded that training in resourcefulness, original thinking and intellectual honesty are primary objects in an engineering course, it is hard to see how they can be encouraged by mere insistence on numerical accuracy of answers which, by the nature of the case, makes almost mandatory the use of a standardized procedure. It is also hard to see how the several problems with careful checking of each, advocated by Mr. Sanks as requisite to his system, can be crowded into a two hour examination, let alone the fifty minutes available for frequent tests during the course, and still leave time for original thought.

To quote a complaint from one of my students several years ago, "Professor Upson expects us to think and we haven't time to think." As a means of providing time for such thought, let us not overemphasize numerical accuracy, important as it is, but realistically admit that the undergraduate student has other important things to learn, one of them being a recognition of human frailty in general, as so often exemplified in the pronouncements of teachers, Mr. Sanks' provocative article included.

Why be an Instructor?

By MARTIN LEVINE

As a new instructor, I attempted adequately to answer this question. It is now my intention to present the problem, as I see it, without supplying the answer, which as yet I have not obtained. Most readers are acquainted with the difficulties in obtaining qualified instructors. Most of you have in mind both the advantages and disadvantages of the teaching profession. It is my intention to

review carefully the major advantages and disadvantages to teaching engineering.

On the side of disadvantages, the subject of salary looms as the largest and, to many, the only problem. In order to adequately maintain a suitable standard of living for his family, an instructor must resort in many instances to a second job, university research project, or a reduced standard of living. In compensation for low salary, increased leisure is often cited. To the good instructor such leisure is a fiction; for even if he were financially secure, which most are not, he must consume a large number of hours aiding the inferior students and challenging the superior ones. It is frequently implied or stated that as teaching becomes repetitive it will not require as extensive a preparation. It shall then become necessary in my opinion, for the good instructor to devote the additional free time to aiding the poorly equipped students in the mastery of the subject.

An advantage often cited is the prestige in teaching. In the present day American society, which is a highly materialistic one, the earner of the largest income receives the greatest ovations. The number of eulogies to good instructors are insignificant to the number for entertainers in the fields of radio, television, movies and sports. The prospect of preparing a textbook for not only the pecuniary return but also the added prestige involved in such an undertaking is frequently mentioned. The unavailable time, if suitable instruction is desired, and the need in most cases to hold professorial rank to have a book become acceptable to schools in general makes this idea unsuitable for the general instructor.

The moral obligation to society is stressed frequently. Forgotten is an instructor's obligation to his family and the further fact that the American society in many cases ignores moral obligation when financial award is present. An individual who becomes an instructor must devote a large part of his time to a secondary occupation in order to have the wherewithal to maintain a living standard in his community equal to that of other professional people. In order to obtain instructors at the low salary scale, in many instances, marginal instructors are employed, instructors who work on a part time basis, instructors that devote time to secondary employment and the use of instructors on research assignments which in no way enhance instruction at the undergraduate level. At the university level, use of graduate students for undergraduate instructors is employed to the detriment, in my opinion, of the average technical student, since the graduate student is not interested in teaching as an occupation. In the graduate school, close association with a professor on a research project alleviates some of this difficulty, but not all, since in many cases the research is the end desired rather then the student's education.

In my limited personal contact with the subject I found no suitable incentive for an instructor to be just a good instructor. Salvation is spiritual and this may not, and usually does not, satisfy his family demands upon him. The number who can overcome the financial obstacle are few and far between. I am proposing no solution here, but rather presenting the problem for open discussion. A look at job opportunities offered to engineering students just graduating shows a salary average of approximately $4800.00 per year compared to an instructor of engineering who on a 9-month basis receives approximately $4000.00 and on a 12-month basis on the average receives $5000.00, reference: *faculty salaries in land-grant colleges and state universities*, 1951–52, Circular No. 358, U. S. Department of Health, Education, and Welfare: Office of Education.

An engineering analysis considering the economic, financial, intangible factors in being an instructor would show in an "In-Favor Analysis" that an incentive of some type is necessary to attract the best instructors to the teaching profession, rather than mere platitudes.

National Engineers' Week

(Week of Feb. 19, 1956)

National Engineers' Week is an effort to acquaint the public with facts about the engineering profession and the role it plays in our national welfare. To be most effective, this information must be presented in a dramatic, interesting, and stimulating manner, trying to reach all possible channels of public information and all segments of the American people.

A profession cannot fully carry out its fundamental obligation of public service if the public is not aware of the many ways in which the profession can be of service to them. It is, therefore, one of the duties of a profession to keep the public informed as to what the profession does and how it affects everyday life. In the case of such professions as law and medicine it would seem hardly necessary to explain their functions to the public. These professions are well known because long ago they realized the need for establishing good public relations and they have carried on appropriate and successful programs of public information. The American Bar Association, the American Medical Association, and their state and county units still continue this work and regard it as one of their most important functions.

Because of its division into numerous technical societies, the engineering profession as a whole has never undertaken a program to make its functions known and appreciated by the public. Yet in these days, more than ever before, it is becoming essential for our profession to do so.

The struggle for the survival of the free world is largely a technological struggle in which the professional engineer plays a vital and indispensable role. Continuance of our way of life is dependent upon maintaining our position of technical supremacy, which demands the highest quality of technical ability. To maintain America's present leadership, it is essential that we attract the most talented, the most creative minds of our young men and women to engineering and scientific pursuits.

It has been truly said that the finest youth are attracted to that profession to which their country attaches most prestige. In totalitarian countries, a few men can decree which profession shall have such prestige. Behind the "iron curtain," strong incentives are offered to young men and women to follow engineering and scientific careers. In a free country like ours, we must attain the same result by selling the idea that the building up of the prestige of the engineering profession is the patriotic duty of every member of our profession. This can be done most effectively by a continuous program of public information.

Cold facts and statistics lack in public appeal, and are not readily assimilated. To impress the public with the importance of our message and to do it quickly and effectively, we must dramatize factual information with emotional appeal, and present it with enthusiasm. National Engineers' Week affords the opportunity for such presentation.

An eminent engineer recently wrote:

"The great American public is quick to appreciate ability. And I have found that the public does recognize the engineer in thinking that he can do just about everything there is to be done. But the public

sees only the completed product; it does not appreciate the engineer's part in it. It is as if the fans knew only the score of the ball game after it was finished. If the public could intimately see and understand the hits and runs and errors of the engineer as he works to perfect his product—to complete his ball game—its appreciation would be boundless for the wonders he performs."

We can feel justly gratified with the growing response of the profession to the public service programs of National Engineers' Week. Joint participation in such programs by various engineering and technical societies demonstrates to the public the essential unity of the engineering profession.

ENGINEERS JOINT COUNCIL

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Teaching Positions Available

ASSISTANT OR ASSOCIATE PROFESsor (rank depends upon training and experience) to teach Engineering Drawing and some courses in Industrial Engineering. Nine months basis with possibility of one term Summer School. Opening February 1, 1956. Location, Southwest. DEC–1

TWO INSTRUCTORS ENGINEERING drawing preferably with degree in some branch of engineering, but degree in Industrial Arts will be considered. Teaching period is nine months with possibility of some six week summer school term. Opening February 1, 1956. Location, Southwest. DEC–2

INSTRUCTOR OR ASSISTANT PROFESsor to teach fundamental electrical engineering courses in Midwest engineering college. M.S. degree and/or teaching experience desirable. Position available January 1, 1956 or later. Good salary for qualified person. DEC–3

PROFESSOR (ASSISTANT, ASSOCIATE, or full rank). Candidate should have M.S. degree; experience with High Frequency very desirable. Teaching assignments: basic electronics, communications and fundamental electrical engineering courses. Rank and salary will depend upon experience and training. School location on a large campus in northwest Detroit. Cooperative program. Position open for terms starting either November 20, 1955, or February 21, 1956. DEC–4

ASSOCIATE PROFESSOR, PH.D. DEsirable, M.S. essential, with teaching and professional experience in civil engineering, to teach graduate and undergraduate subjects in two subdivisions of civil engineering at Midwest university. Instructor or Assistant Professor, with Ph.D. degree or willing to work towards it, to teach principally undergraduate subjects in two subdivisions of civil engineering. DEC–5

ENGINEERING FACULTY OPPORTUNity at Midwest state college. The Chairman in the Physics Department, salary open. Electrical Engineering Instructor or Assistant Professor in the Power field. Mechanical Engineering Instructor or Assistant Professor in Physics. Opportunity for graduate study. Housing available. Positions start September, 1956. DEC–6

ASSISTANT PROFESSOR AND INstructor at small Midwest engineering college in department of Civil Engineering. Positions for spring or fall semester 1956-57. Assistant professor must have special training or experience in sanitary engineering. Must have broad interest as applied mechanics and strength of materials as well as civil engineering are taught. Graduate studies available at nearby university. DEC–7

ASSISTANT AND ASSOCIATE PROfessor in dual teaching positions in Electrical Engineering. Applicants are particularly desired from interest in power, servomechanisms, or computers. Write resume of educational background and experience to Dean Ralph G. Galbraith, College of Engineering, Syracuse University, Syracuse 10, New York.

APPLIED MECHANICS AND CIVIL engineering teachers urgently needed to begin about January 26, 1956. Write J. H. Murdough, Head of Civil Engineering Dept., Texas Technological College, Lubbock, Texas.

STAFF OPENINGS IN CIVIL, ELECtrical and Mechanical Engineering; M.S. or Ph.D.'s desired. Salaries commensurate with qualifications. College of Engineering, Duke University, Durham, North Carolina.

HEADSHIP OF INDUSTRIAL ENGIneering Department open. Requires background of progressively responsible management positions in industry or government. Good record of publications. Research and teaching experience desirable. Age, 35–50; salary, open; position to be filled prior to September, 1956. Write Chairman, Nominating Committee, Industrial Engineering Department, The Pennsylvania State University, University Park, Pennsylvania.

INSTRUCTOR AND ASSISTANT PROfessor in Mechanical Engineering to teach Heat-Power subjects, Manufacturing Processes, or design. Opportunity to study for Graduate Degree. Salary depends upon qualifications. Associate Professor to teach and develop courses in the field of Metallurgy. Ph.D. degree and teaching experience desirable. Apply to Chairman, Department of Mechanical Engineering, University of Texas, Austin 12, Texas.

New Members

ALDEN, CARROLL RUSSELL, Associate Professor of Electrical Engineering, Ohio Northern University, Ada, Ohio. Lawrence H. Archer, Alton D. Taylor.

ASKOUNES, PERICLES N., Administration Chairman, Dealer Coop Program, General Motors Institute, Flint, Michigan. Harold M. Dent, C. A. Brown.

BARYLSKI, JOHN ROBERT, Assistant Professor, Mechanical Engineering, New Bedford Institute of Textiles and Technology, New Bedford, Mass. Howard C. Tinkham, Lenine Gonsalves.

BERENDS, HENRY EVERETT, Instructor of Mechanical Engineering, Bradley University, Peoria, Illinois. R. B. Gibbs, F. C. Mergen.

BRADFORD, JOHN R., Dean of Engineering, Texas Technological College, Lubbock, Texas, O. A. St. Clair, C. V. Bullen.

BURNS, HUGH, Instructor in Engineering Mechanics, New York University, New York, New York. F. L. Singer, C. Morris.

CAHN, CHARLES R., Assistant Professor of Electrical Engineering, Syracuse University, Syracuse, New York. Robert P. Lett, B. H. Norem.

CHOPPESKY, (REV.) JOHN CORNELIUS, Acting Dean, Regent of Parks College, Saint Louis University, East Saint Louis, Illinois.

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COMO, JACK, Assistant Professor of Mechanical Engineering, New York University, New York, N. Y. L. O. Johnson, A. H. Church.

COOK, WILLIAM H., Assistant Professor of Civil Engineering, Loyola University of Los Angeles, Los Angeles, California. D. E. Whelan, Jr., Fr. L. C. Werts.

COTTOM, MELVIN CLYDE, Assistant Professor of Electrical Engineering, Kansas State College, Manhattan, Kansas. E. L. Sitz, O. D. Hunt.

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EZEKIEL, FREDDIE D., Assistant Professor of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass. W. W. Murray, J. Kaye.

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GROSVENOR, NILES E., Assistant Professor of Mining, Colorado School of Mines, Golden, Colorado. F. R. Campbell, L. J. Parkinson.

HEIMAN, DAVID WILLIAM, Director, Department of Military Art, The Engineer School, U. S. Army, Fort Belvoir, Virginia. W. N. Underwood, E. E. Packard.

HEIMER, ROGER C., Associate Professor of Mechanical Engineering, Villanova University, Villanova, Pennsylvania. J. S. Morehouse, J. J. Gallen.

HORN, TYREE R., Instructor, Pennsylvania State University Center, York Pennsylvania. E. M. Elias, V. E. Neilly.

HOUGH, CHESTER CARROLL, Instructor of Engineering, The Pennsylvania State University, University Park, Pa. V. E. Neilly, C. G. Mills.

JERDE, ROBERT S., General Personnel Relations Supervisor, Wisconsin Telephone Company, Milwaukee, Wisconsin. R. J. Panlener, A. B. Drought.

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MINOR, BEN, Lecturer, Electrical Engineering, City College of New York, New York, N. Y. C. Froehlich, H. B. Hansteen.

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RAVILLE, MILTON EDWARD, Associate Professor of Applied Mechanics, Kansas State College, Manhattan, Kansas. F. J. McCormick, C. H. Scholer.

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SAVAGE, CHARLES F., Consultant in Professional Relations, General Electric Company, New York, N. Y. M. M. Boring, H. W. Guildthorpe.

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WEST, JOHN TUNNELL, JR., Executive Secretary, Pennsylvania Society of Professional Engineers, Harrisburg, Pa. K. W. Riddle, W. J. Stevens.

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WILLIAMS, EDWIN T., Associate Professor of Chemical Engineering, The Pennsylvania State University, University Park, Pa.

YEN, JUI LIN, Lecturer, Electrical Engineering, University of Toronto, Toronto, Canada.

55 new members
162 previously added

217 new members this year

Young Engineering Teachers' Paper Contest

RULES

Eligibility: Members of ASEE who are not over 35 years of age (their 36th birthday must not be before June 1, 1956).

Awards: First prize $200—Second prize $100.
Honorable mentions as determined by the Judging Committee.

Presentation of Awards: The awards are known as the "President's Awards." They will be presented to the recipients by the President of the Society at the Annual Banquet at Iowa State College, June 28, 1956.

Subject: Papers should deal with some constructive phase of improvement of engineering education. Participants are encouraged to use their own judgment in selecting appropriate subject matter.
The following are suggestions of possible subjects:

1. Professional development of the Young Engineering Teacher.
2. How should the student be helped to learn to deal with situations that are new to him, on his own initiative and with well-ordered professional thinking?
3. To what extent should modern physics be included in the engineering curriculum and how should this be done?
4. What areas of physics, chemistry, mathematics and biology not now taught in engineering curricula are likely to be translated into significant engineering practice in the next 15 years and how should this influence present curricula?
5. To what extent and in what manner should undergraduate instruction acquaint the engineering student with the methods of research and with recent research developments in engineering and closely allied sciences?
6. What should be taught of the art of engineering as contrasted with its science?
7. What basic science, mathematics and communication principles and skills can best be taught by separate department staffs and what part by integration into engineering courses?
8. What can be done in college to prepare the young engineer to continue to learn after his formal education is ended?
9. How should non-major courses in engineering such as electrical engineering for non-electricals be planned as to content and method?

Length of Paper: Not to exceed 2500 words.

Submission of Entries: All entries should be submitted to the Chairman of the ASEE Section in which the member resides before March 1, 1956. Names and school affiliations of Section Chairmen are published each month on the page in the Journal of Engineering Education designated "Section Meetings." Papers submitted in the contest last year or in other contests are not eligible for this year's contest.

Judging: Each Section of ASEE will appoint a Judging Committee to select the best paper from the Section. This paper will be submitted to the ASEE Secretary before April 1, 1956.

The winning papers from the various ASEE Sections will be submitted to a Final Judging Committee for the final selection.

Here is an opportunity to gain national distinction. Good luck!

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

NOMINATION BLANK

"ARTICLE XI, Section 3. (Election of Officers) By means of a form to be printed in The Journal of Engineering Education or in the preliminary program of the annual meeting, an opportunity shall be given to individual members of the Society to submit names of persons to be considered for said officers. These names, on the form provided, shall be sent to the Secretary of the Society not less than sixty (60) days prior to the annual meeting; and the Secretary shall submit the suggested names to all members of the Nominating Committee."

In order to make the election of officers of the Society as democratic as possible, members are urged to fill out the nomination form and return before April 1, 1950 to the Secretary, W. Leighton Collins, University of Illinois, Urbana, Illinois.

I nominate the following members of the Society for officers:

For President .....

.....

For Vice-President .....
(In Charge of General and Regional Activities—two years)

.....

For Treasurer .....

.....

Signed .....

Title .....

Institution .....

Date .....

Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	Carnegie Institute of Technology	April, 1956	J. W. Graham, Jr., Carnegie Institute of Technology
Illinois-Indiana	Purdue University	May 12, 1956	O. W. Witzell, Purdue University
Kansas-Nebraska	University of Wichita	Oct. 26–27, 1956	J. K. Ludwickson, University of Nebraska
Michigan	Wayne University	May 5, 1956	G. H. Howell, Wayne University
Middle Atlantic	New York University	Dec. 3, 1955	C. C. Carr, Pratt Institute
Missouri-Arkansas	St. Louis University	April 7, 1956	J. B. Macelwane, St. Louis University
National Capital Area	Capital Radio Engineering Institute	Oct. 11, 1955	D. C. Jackson, Jr., Aberdeen Proving Ground
New England	University of Maine	Oct. 8, 1955	W. S. Davis, University of Maine
North Midwest	South Dakota State College	Nov. 4–5, 1955	L. L. Amidon, South Dakota State College
Ohio	Ohio State University	April 28, 1956	E. C. Clark, Ohio State University
Pacific Northwest	University of Washington	May 10, 11, 12	J. B. Morrison, University of Washington
Pacific Southwest	California Institute of Technology	Dec. 28–29, 1955	R. G. Moses, Pasadena City College
Rocky Mountain	Denver University	April 28	W. H. Parks, University of Denver
Southeastern	Tulane University	April 5, 6, 7	D. W. Dutton, Georgia Institute of Technology
Southwest	Texas Western College	March 30–31, 1956	H. K. Bone, University of Oklahoma
Upper New York-Ontario	Syracuse University	Oct. 14–15, 1955	B. H. Norem, Syracuse University

Members of the Society are welcome at all Section Meetings

ENGINEERS JOINT COUNCIL—GENERAL ASSEMBLY

Hotel Statler, New York City

JANUARY 26 and 27, 1956

Manpower Utilization

Thursday, January 26th, will be devoted to manpower sessions. The over-all theme of the varied presentations is Improved Utilization of Engineering Manpower. The morning sessions will provide a presentation and discussion of the meaning of Public Law 305—the Reserve Forces Act of 1955—To the utilization of engineers, scientists and other specialized personnel. The three persons bearing top governmental responsibility for these matters have graciously agreed to be present for short formal presentations followed by discussion. They are General Lewis B. Hershey, Director of the Selective Service System; Mr. Carter L. Burgess, Assistant Secretary of Defense for Manpower and Personnel, and Brigadier General Carlton S. Dargusch, Assistant Director for Manpower in the Office of Defense Mobilization. This will be perhaps the first time that this triumvirate bearing major responsibility for military and related manpower problems in government will have been available on the same platform to present an authoritative over-all picture.

The luncheon speaker will present under the title "Brainpower—Our Most Precious Asset" a current picture of the relation of our nation's brainpower potential to estimated needs. For this purpose the results of the EJC Special Surveys Committee Survey of Demand for Engineers and Engineering Technicians, a study now under way, will be presented. The implications of this and long range evaluations of our manpower need as against our potential will provide an interesting backdrop for the afternoon sessions.

"Extending Engineering Manpower by Utilizing Balanced Teams of Engineers and Engineering Technicians" is the theme of the afternoon session. This will present a specific analysis of the principal ideas and problems involved in the efficient integration of engineers and engineering technicians on the engineering team.

Dr. Eric A. Walker of Pennsylvania State University will open the session with an assessment of the "Preparation and Relative Capabilities of Engineers and Engineering Technicians." This will be followed by a presentation by Dr. L. E. Saline of the General Electric Company on the "Recruitment, Training and Placement of Technical Institute Graduates—A Centrally Controlled Program." Dr. S. W. Herald, Engineering Manager, Air Arm Division of the Westinghouse Electric Corporation will then discuss "Planning the Ideal Engineer-Engineering Technician Team in a New Engineering Department."

This will be followed by a series of short presentations on the specific records of achieving an efficient engineering technician team in various industries. These will include the Automotive Industry, the Aircraft Industry, Heavy Construction Industry, Petroleum and Chemical Industry and Government Public Works Activities.

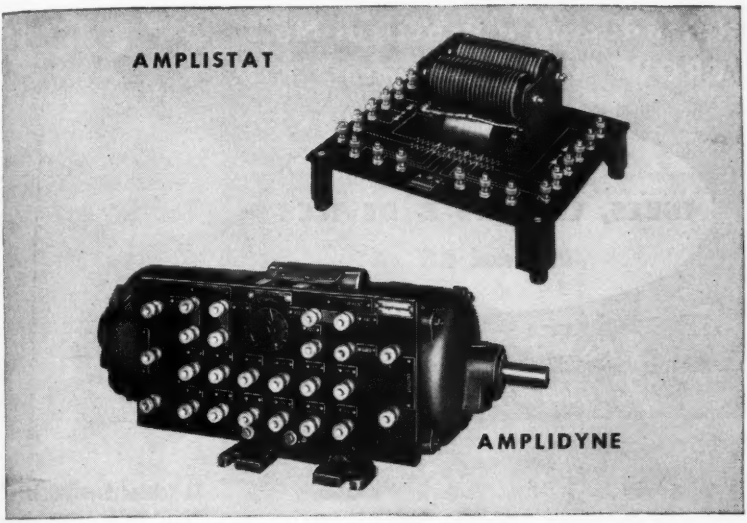
Growth Patterns

The morning of Friday, January 27th, will be devoted to a discussion of the Growth Pattern of the Engineer. Panel moderator will be Mr. Sidney D. Kirkpatrick of the McGraw Hill Book Company. The Educator's viewpoint will be discussed by Dean Morrough P. O'Brien, chairman, Dept. of Engineering, University of California. Industrial aspects will be presented by Mr. James H. Taylor, Director of Public Relations, Procter & Gamble Company, Cincinnati, Ohio, and a discussion of the Employee's Viewpoint by Mr. Robert Nelsen, General Electric Company, Cincinnati, Ohio. Various human problems in engineering will be discussed by Mr. Earl Brunner of Rogers, Slade & Hill, New York City.

Dr. S. C. Hollister, Dean, School of Engineering, Cornell University, and a member of the Hoover Commission, will speak on the "Objectives of the Hoover Commission." The afternoon will then be devoted to a presentation of "The Engineering Aspects of the Hoover Commission Reports." Dr. Mervin Kelly, President, Bell Telephone Laboratories will discuss Research and Development Aspects of the Hoover Commission Reports, and Admiral Ben Moreell of Jones & Laughlin Steel Company will present a discussion of the Hoover Commission and its Water Resources Report.

At dinner on Friday evening, Dean Thorndike Saville, retiring President of Engineers Joint Council, will address the Council. The guest speaker, Mr. Walker L. Cisler, President of the Detroit Edison Company, will present "A World Look At Usefulness Of Nuclear Power."

(The Assembly is open to members of ASEE. For officers and organization of EJC, see page 405.)



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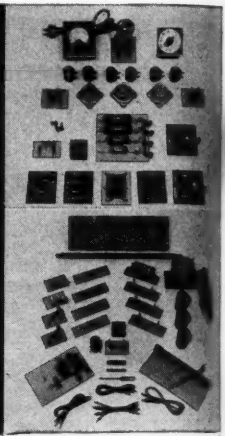

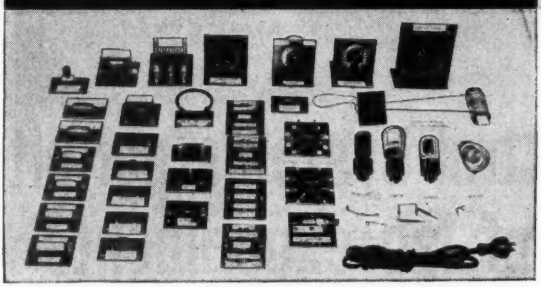

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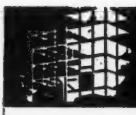

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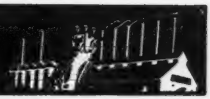

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